Final Degree Project

Industrial Technology Engineering Degree

ANALYSIS OF THE IMPLEMENTATION OF THE BIOMASS SUPPLY CHAIN IN CATALONIA

PROJECT REPORT

Author: Christian Dalmau Baraza
Director: Francesc Xavier Gavaldà Aran
Call: July 2017

ETSEIB

Escola Tècnica Superior d’Enginyeria
Industrial de Barcelona

UPC

1. Resum

L'impuls de les energies renovables és fonamental per poder evolucionar cap a un model de sostenibilitat energètica de futur, i en un context de crisi com l'actual, pot afavorir el desenvolupament socioeconòmic i la creació de llocs de treball d'una manera sostenible. El sector de les energies renovables és innovador i té unes previsions de creixement importants, i dins d'aquest, la biomassa forestal pot esdevenir, avui dia, una de les renovables amb més potencial al nostre territori.

La biomassa forestal és la energia renovable que té més capacitat de crear ocupació professional, sobretot en l'àmbit rural, ja que fixa població i afavoreix la cohesió social i territorial i el desenvolupament local.

L'acumulació de biomassa en les zones boscoses és cada vegada més gran ja que els aprofitaments forestals suposen només el 30% del creixement del bosc. Això és degut principalment a la poca rendibilitat econòmica de les explotacions forestals i a la sortida comercial reduïda de la seva fusta, la qual cosa comporta un augment important del risc d'incendi.

Una gestió sostenible i adequada de la biomassa forestal pot permetre prevenir aquests incendis, donar equilibri territorial al medi, protegir la flora i la fauna, aportar recursos energètics renovables i generar economia i ocupació local.

És per això que els objectius principals d'aquest projecte seran:

- Analitzar la situació actual de la biomassa així com les possibilitats que ofereix.
- Avaluar i diagnosticar la capacitat de penetració d'aquesta com a font d'energia a Catalunya, analitzant les zones amb elevada superfície forestal i/o elevat índex d'atur i que mostren a la vegada interès i possibilitats cap al sector de la biomassa.
- Presentar un pla d'acció per al desenvolupament de la cadena logística forestal de biomassa a Catalunya.

Per tal de complir aquests objectius, en primer lloc es durà a terme un anàlisis de l'entorn i un estudi de mercat amb el seu respectiu DAFO que ens permetrà situar-nos en el nou món d'oportunitats que presenta la biomassa.

Tot seguit s'analitzarà la situació actual de la biomassa a Catalunya i es determinarà mitjançant un anàlisis comparatiu la situació més òptima per implantar la cadena logística de subministrament.

Un cop coneguda la aquesta localització, es farà una presentació dels municipis que engloba, la distribució forestal, el seu risc d'incendi i la xarxa de carreteres. En la mateixa direcció, es quantificarà la biomassa del territori escollit, es presentarà la logística de subministrament que s'utilitzarà per l'extracció d'aquesta biomassa i s'avaluarà la demanda potencial d'energia que presenta la localització així com els seus principals clients.

Finalment, es proposarà un pla d'acció amb el seu horitzó temporal representat amb un diagrama de Gantt per a desenvolupar la cadena logística de subministrament de biomassa forestal.

Cal remarcar però que aquest estudi no inclourà termes de rendibilitat econòmica ni entrarà dintre de les plantes i centrals de biomassa. Seran línies obertes d'estudi que presentarà el treball per a futures recerques.

2. Abstract

The impulse of renewable energies is fundamental to be able to evolve towards a model of future energy sustainability, and in a context of crisis such as the current one, can favor socio-economic development and the creation of jobs in a sustainable way. The renewable energy sector is innovative and has significant growth forecasts, and within this, forestry biomass can become, today, one of the renewable ones with greater potential in our territory.

Forestry biomass is the renewable energy that can most help the creation of new jobs, especially in rural areas, since it fixes population and favors social and territorial cohesion and local development.

The accumulation of biomass in forested areas is increasing as forest utilization accounts for only 30% of forest growth. This is mainly due to the low economic profitability of forestry operations and the reduced commercial output of their wood, which entails a significant increase in the risk of fire.

Sustainable and adequate management of forest biomass can help to prevent these fires, give territorial balance to the environment, protect flora and fauna, provide renewable energy resources and generate local economy and employment.

That is why the main objectives of this project will be:

- Analyze the current situation of biomass as well as the possibilities that it offers.
- Evaluate and diagnose the penetration capacity of this as a source of energy in Catalonia, analyzing areas with high forest area and/or high unemployment rate, which show both interest and possibilities to the biomass sector.
- Present an action plan for the development of the forest biomass logistics chain in Catalonia.

To achieve these objectives, we will first carry out an analysis of the environment and a market study with its respective SWOT that will allow us to place ourselves in the new world of opportunities presented by biomass.

The current situation of biomass in Catalonia will be analyzed and with a comparative analysis it will determined the most optimal situation to implement the supply chain.

Once this location is known, a presentation will be made of the municipalities that it englobes, the forest distribution, its fire risk and the road network. In the same direction,

the biomass of the chosen territory will be quantified, the supply logistics to be used for the extraction of this biomass will be introduced and the potential energy demand presented by the location as well as its main clients will be evaluated.

Finally, an action plan will be proposed with its time horizon represented by a Gantt diagram to develop the logistic supply chain of forest biomass.

It should be noted that this study will not include terms of economic profitability nor enter into plants and biomass plants. They will be open lines of study that will present the work for future research.

3. Index

4. Introduction to biomass

4.1 Renewable energies

Nowadays the global energy supply is based in some resources that in their majority, come from fossil fuels such as petroleum, carbon and natural gas. That resources generate environmental effects as the greenhouse effect, the acid rain and the global warming. In addition, these are limited and the fossil fuel exhaustion is a reality at the present time due to the rhythm that our society consume them.

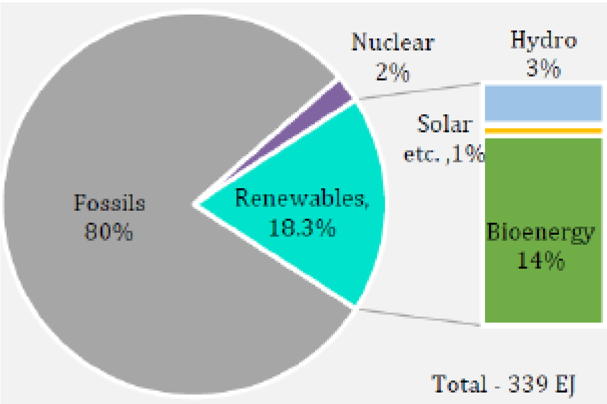

Figure 1: Primary energy consumption worldwide. Source: WBA.

Furthermore, it has to be added the huge imbalance between rich and poor countries, as the energetic resources are placed in concrete zones of the planet, what causes big inequality between countries and a scene that is unsatisfactory for the social and political balance.

That risks makes our current energetic system unsustainable and it appears the necessity to look for an alternative: the renewable energies.

These energies are a series of different energetic sources that have common characteristics:

- Are resources that are distributed around the planet, what guarantees an own supply.
- Have a low environmental impact.

In consequence, these are a key element to improve the negative effects that provide the fossil fuels to the environment. In this way, it is guaranteed the use without limit of the inexhaustible natural sources of the different renewable energies (biomass, solar, hydraulic, wind, geothermal, marine, tides).

4.2 Biomass

The biomass is the set of organic matter, from vegetal or animal origin, and the materials that come from their natural or artificial transformation used with the aim of producing energy. The 2009/28/CE Directive related to the foment use of the energy coming from renewable sources, defines the biomass as "the biodegradable fraction of the products, wastes and residues of biological origin that come from agricultural activities (included de substances of vegetal and animal origin), silviculture and the related industries, included fishing and aquaculture, as well as the biodegradable fraction of the industrial and municipal residues."

It is a very wide concept that include from the residues of the forestry, agricultural and livestock industry activities to the organic fraction of the domestic and industrial residues, going by the by-products of the processed food industries and the wood transformation.

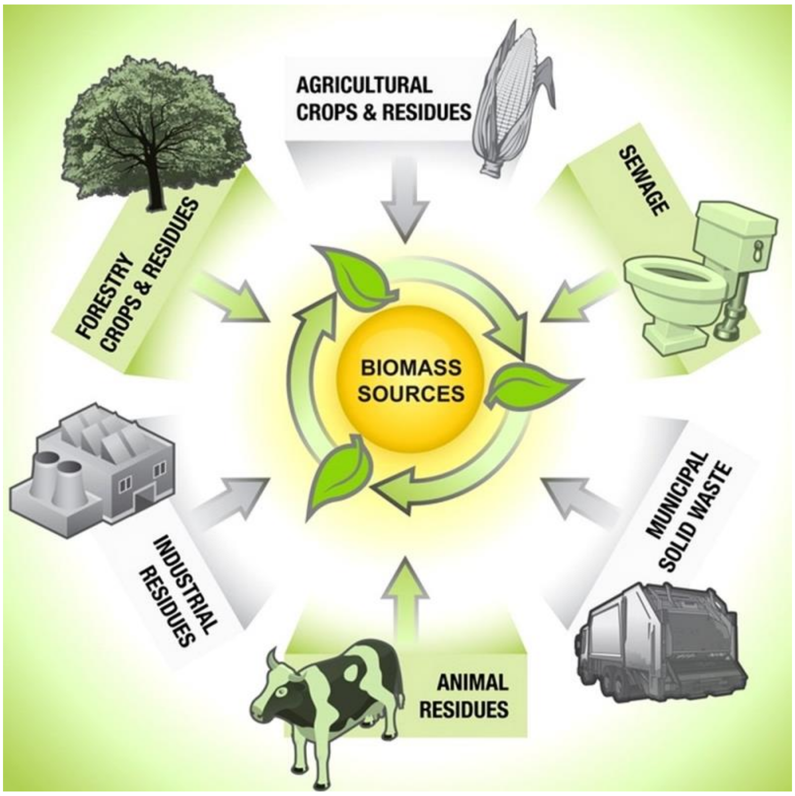

Figure 2: Biomass sources. Source: The Earth Project.

4.2.1 Residual biomass and its classification

The residual biomass is the one that is generated in any human activity, principally in the productive processes of the agriculture, forestry or livestock sector, as well as the produced in the city centre. It is classified according to its origin in:

1. Forestry residues: the ones that are obtained in the processes of maintenance and cleaning of the mountain, with those that are produced in the forest exploitation for the industrial use of the wood.
2. Agriculture residues: those that are got from the cultivated plant when it is separated the part that is going to be used as an aliment or as a raw material in the industry, such as the cereal straw.
3. Livestock residues: generated by the animals when it is used the vegetal biomass as food. It can be originated by a live animal (manure) or by a dead animal (slaughterhouse waste).
4. Industrial residues of forestry base: produced mainly by the timber and paper industries.
5. Agricultural and processed food industry: practically all the industries that transform agricultural products produce biomass residues. It is therefore that in this sector it is necessary to stand out these industries that generate residues that effectively are susceptible to be used with energetic aims. In the Mediterranean ambit stand out the extraction of olive oil, elaboration of nuts and citrus peels.
6. Urban residues: those that are generated in the city center as a consequence of the usual and daily human activity. It is divided in urban solid residues and urban residues waters.

This project is focused on the forestry biomass, an energy that has not exploited all its potential energy yet and that provides a socioeconomic development to the rural zones, as the resources used (forestry residues) are in this region, improving the job and life conditions, at the same time that is done a sustainable use of these resources.

5. Environment analysis

5.1 Mundial context

Various biomass projects have been developed by the International Energy Agency (IEA). This agency has calculated that 10% of global primary energy comes from biomass and the resources related to this source, included biofuel liquids and biogas. A big part of this percentage corresponds to poor countries and the ones in current development, where it is the raw material more used for the energy production.

According to FAO 2013 information, some poor countries obtain the 90% of its energy from wood and other biofuels. In Africa, Asia and Latin American it represents the third part of the energetic consumption and for 2.000 million of people it is the principal energy source in the domestic ambit. However, in many occasions, this massive utilization is not realized through the rational and sustainable use of the resources, if not as a desperate way of looking for energy that causes the deforestation of big areas.

Region/subregion	Biomass	
	million tonnes	t/ha
Eastern and Southern Africa	33 385	124.8
Northern Africa	3 711	47.1
Western and Central Africa	81 603	248.7
Total Africa	**118 700**	**176.0**
East Asia	18 429	72.4
South and Southeast Asia	51 933	176.4
Western and Central Asia	3 502	80.5
Total Asia	**73 864**	**124.7**
Europe excl. Russian Federation	25 602	130.7
Total Europe	**90 602**	**90.2**
Caribbean	1 092	157.5
Central America	3 715	190.5
North America	76 929	113.3
Total North and Central America	**81 736**	**115.9**
Total Oceania	**21 302**	**111.3**
Total South America	**213 863**	**247.4**
World	**600 066**	**148.8**

Figure 3: Amount of forestry biomass per region worldwide. Source: FAO.

Biomass could be the way of development of poor countries, avoiding that the increase of the energetic consumption endanger the environment and the security of energetic supply in our society.

While this bet is turned into reality, the concrete previsions of the future are handled by many organizations, establishing that before 2100 the biomass participation in the global production has to be between the 25 and 46% (IDAE). It is an ambitious prevision but it has to be considered that biomass market is constantly growing.

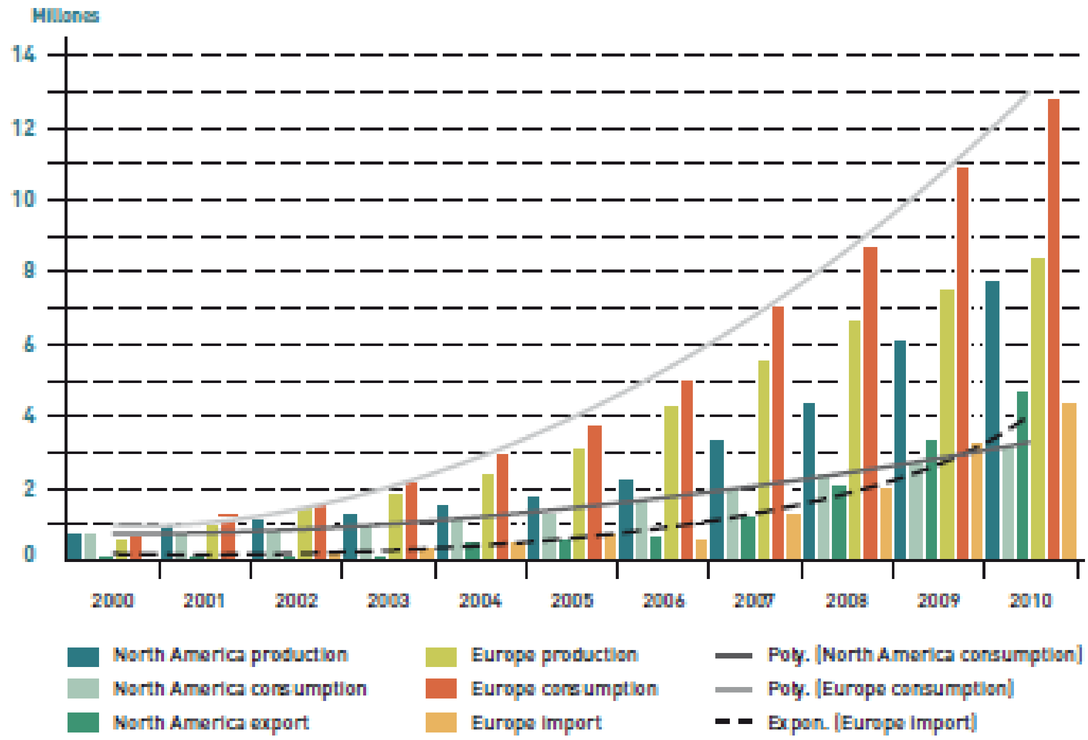

Chart 1: Global evolution of the pellet market. Source: PER 2011-2020.

In this context, ONU (2011) set up its first initiative of Sustainable Energy for All with the aim of double the percentage of the renewable energy use in 2030 as well as to ensure the universal access to the energy and double the rate of energetic efficiency improvements.

5.2 European context

In Europe, the 54% of renewable raw energy come from biomass. Nevertheless, it only supposes the 4% on the energetic total. The majority is destined to the heat generation in single-family homes, neighbourhood communities and central heating networks. In general, around 83% is destined to thermal uses and the remaining 17% to the electricity production. France and the Scandinavian countries are considered the authentic leaders in relation to their number of habitants. For example, Finland covers with biomass the 50% of their heat necessities and the 20% of raw energy consumption.

Different analysis of the European situation point that if the countries more inhabited and with important forestry resources intensify their efforts in this matter, it will be possible to establish the biomass participation in the global production between the 25 and 46% before 2100.

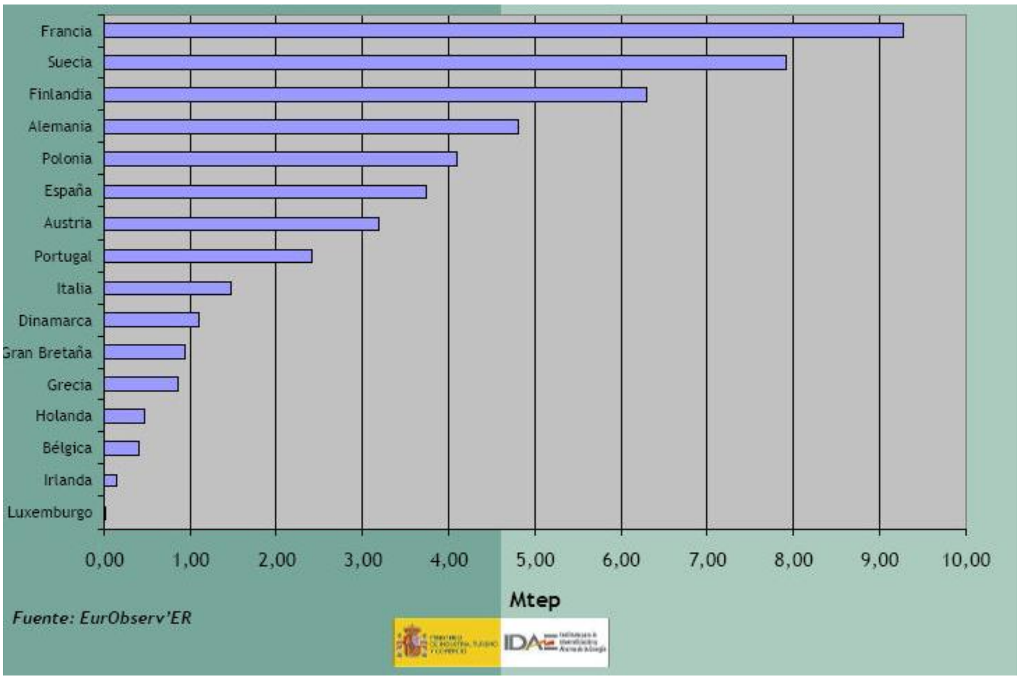

Chart 2: European ranking of the biomass consumption. Source: IDEA.

5.3 National context

At the present, the major part of the final biomass consumption in Spain come from the forestry sector, used in the domestic area, through inefficient traditional systems and forestry industries for thermal and cogeneration consumption.

The available biomass potential in Spain is around 88 million of tons of primary biomass, including forestry andagriculture rests and energetic crops to implant. To this potential is added more than 12 million of tons of secondary biomass obtained from residues of agriculture industries.

In consequence, the established objectives for the biomass consumption of PER 2011-2020 are:

BIOMASS			
	2010	**2015**	**2020**
Electric [MW]	533	817	1350
Heating and cooling [ktep]	3695	3997	4553

Table 1: Residual biomass objectives. Source: PER 2011-2020.

Moreover, the “Plan de Acción Nacional de EnergíasRenovables de España” (PANER) 2011-2020 was developed to fulfil the 2009/28/CE Directive. One of the principal objectives of this plan was a major development of the renewable sources related to the area of electric generation, with a prevision of the renewable energies contribution to the electric generation of the 42.3 % in 2020.

In this context, the environmental, rural and marine ministry elaborated a strategy with the counselling of IDAE that has permitted to identify and quantify the minimum quantities of forestry biomass that can be used in each autonomous community as a renewable energy. This strategy follows the next objectives:

1. Establish the current and future availability resources in the national ambit.
2. Mobilize the residual forestry biomass, boosting its energetic use.
3. Define or adapt the current normative and financial instruments.
4. Facilitate the development of a competitive and sustainable market and a residual biomass supply chain.
5. Set the possibility of continuous sourcing of the residual forestry biomass limiting the exterior energetic dependence.

6. Market study

6.1 Product analysis

The energy production through forestry biomass has three big advantages that makes it unique in comparison to other renewable energies:

- It is the most beneficial renewable energy for the environment and multiplies the reduction of emissions versus fossil combustibles.
- As it can be cultivated and improved its productive development, is the renewable source that generates more employment by unity of produced energy and its crop allows social cohesion and wealth creation, especially in rural zones, giving then an alternative to the agriculture employment which nowadays has a poor occupation percentage (5,9% in Spain and 2,6% in Catalonia).
- It is the most stable renewable source, able to produce energy 24 hours a day as it does not depend on wind, sun or water. In addition, our country has some unique conditions for its development, what can contribute to reduce the energetic importations.

Beyond the environmental advantages that come from the sustainable forestry management, forestry biomass as an energy source also can give a major social and economic potential favouring the currently and future situation in our country:

- The biomass exploitation could be a key contributor in the national investment.
- Forestry biomass development could let to reduce up to 104 M €/year the expenses associated with fires.

6.2 Necessity analysis

Nowadays the climate change is a global preoccupation, motived in big measure for the emissions increase produced by a major energy consumption of the planet.

More than a half of the CO_2 contributed to the atmosphere derives from electricity and heating generation and the transport, sectors in where it is fomented the more ecologic alternatives such as biomass and biodiesel.

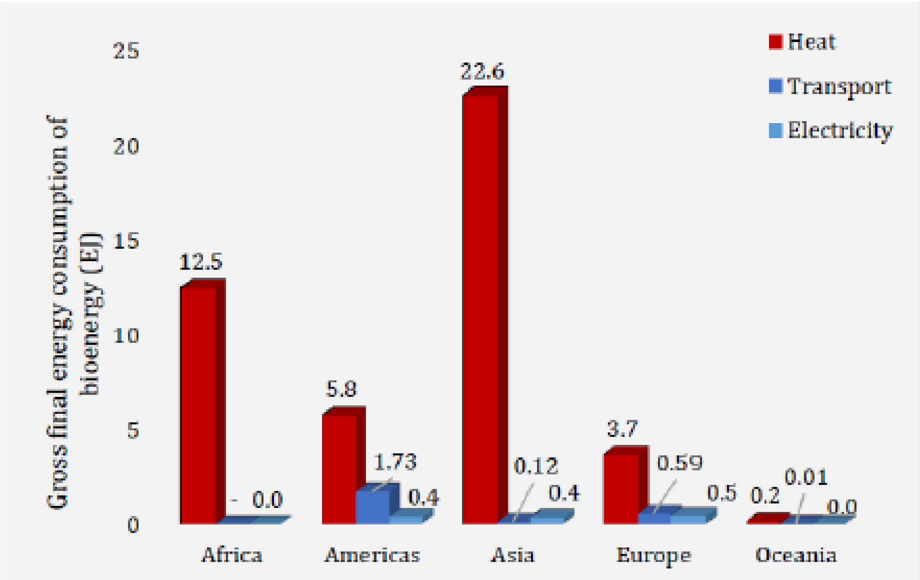

Chart 3: Energy consumption by final destination worldwide. Source: IEA.

The renewable energies in Spain have evolved to a growing participation in the energetic system. The biomass could satisfy during the next 15 years the 15% of the electric energy demand. In comparison with other kinds of renewable sources, such as wind or solar energies, biomass presents the advantage that it could be stored and used when it is required. However, in order to make the installation profitable it is essential to have a biomass source near and have enough energetic consumption.

There are different sectors in where the biomass resource should be a priority:

- Biomass to produce heat: The sector that consumes more biomass without any doubt is heating. The procedure used is simple and inexpensive from the technological point of view. Nevertheless, it is the sector in which the biomass grows more slowly.
- Biomass to produce electricity: The renewable energies give a lot of possibilities to produce electricity. The biomass has to be developed in this sector because it only represents the 3% of the total production. For example, the energies more used in this field are the wind and hydraulic with a 51% and 36% respectively. The aim of the biomass is to reach them and give another powerful alternative for the electricity production.

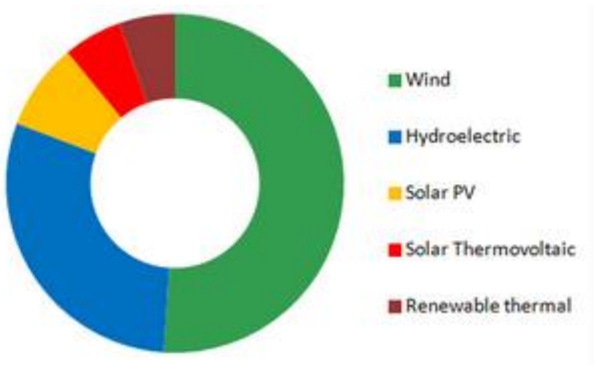

Chart 4: Components of renewable electricity coverage in Spain 2015. Source: Wikipedia.

Nowadays biomass in Catalonia is a little used energy that should have many more relevance. Taking into account the quantity of possibilities for the generation of this kind of energy, biomass should take a more important role in the contribution of renewable energy in this community.

At the present, no one of the more important biomass plants in Spain is situated in Catalonia. These are located in communities where it has been given a major importance to this kind of energy such as Galicia, Andalusia, Castile-La Mancha and Castile-Leon.

Catalonia, due to the elevate forestry resources, must consider the forestry biomass as a part of the resources that contribute to the production of renewable energy and impulse a huge development in this field.

6.3 Price analysis

The forestry residues are the easiest ones to take advantage of their energy and at the same time the ones that involve a major quantity of manpower for its collection.

It has to be stood out that 70% of the investment in this kind of biomass is done with national suppliers. Biomass could contribute to improve the commercial balance in 1.350 M €/year if all its potential is used.

The investment costs for its facilities are superior in comparison to the case of conventional combustibles, due to the special characteristics required for the equipment that is able to the biomass in an efficient way.

The costs estimations depend on three fundamental factors:

- Volume and kind of biomass.
- Conversion process.
- Final use of the energy.

In relation to the exploitation costs of the biomass plants, the principal component is the purchase of the biomass. The costs due to the biomass supply vary according to the quantity demanded, the transport distance and the possible treatments to improve its quality. To reduce this costs, it is pretended to install the biomass plants close to important sources of forestry resources.

It has to be taken into account that the investment is important but this future bet could let the development of a new activity in the rural zones, a market with a continue demand and without fluctuations, which generates job positions and supposes a new source of incomes for the local industries and a possible increase of the population, giving place to the appearance of new infrastructures and services in rural areas.

6.4 SWOT analysis

STRENGHTS	WEAKNESSES
Create direct and indirect rural employment	Low investor confidence
Clean and sustainable energy	Difficult logistical coordination and production of resources
Resource manageable, renewable, competitive and of great chemical quality	Extraction costs higher than other biomass fuels
Biomass volume available	Few cases of success yet
OPPORTUNITIES	**THREATS**
Possibility of development in the thermal and	Lack of knowledge on the part of the society

electrical field	and little institutional support
Optimization of forest biomass in the new European directives	Rejection of the large wood industry by competition for the raw material
Reduction of external energy dependence	Promotion and buildings designed for natural gas with individual installations
Contribution to socio-economic development	Uncertainty in supply conditions and final markets

Table 2: Analysis of strengths, weaknesses, opportunities, and threats. Source: self-made.

7. AS IS: Analysis current situation in Catalonia

7.1 Catalonian area distribution: location, territory, forests and roads distribution.

Catalonia is an Autonomous Community belonging to Spain. It's located in the north eastern part of the Iberian Peninsula. It limits with Andorra and France (Northern part), Valencia (Southern part), Mediterranean Sea (Eastern part) and Aragon (Western part).

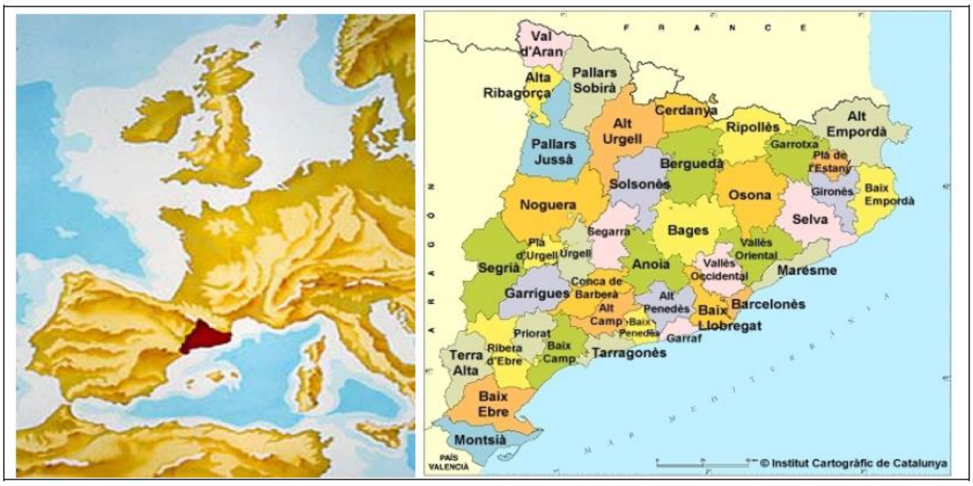

Figure 4: Location of Catalonia in Europe and administrative division of Catalonia in different regions. Source: "Institut Cartogràfic de Catalunya".

Catalonia has a total surface of approximately 32.090 km2 that counts for 6.3% of the whole Spanish surface. In comparison with Spain the most significant differences are seen in a higher percentage of forests and shrub lands and urban areas, while the percentage of the cultivated land and fields and pasture-lands are less than the Spanish average. The different land uses and the forest distribution are given below.

	Catalonia	Spain
Cultivated land (%)	28,6	36,9
Fields and pasture-land (%)	15,9	21,9
Forests and shrub land (%)	43,3	32,8
Lakes and rivers (%)	1	1,2
Urban areas (%)	6,7	4,2
Others (%)	4,5	3

Table 3: Surface and land use of Catalonia and Spain in a surface of 1000 km^2. Source: IEFC.

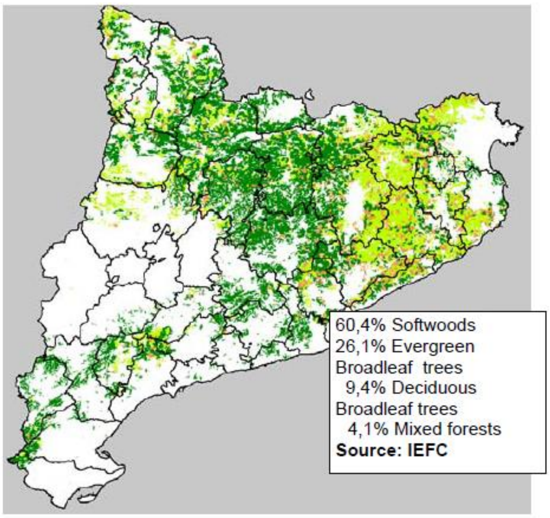

Figure 5: Forest distribution in Catalonia. Source: IEFC.

On the whole Catalan territory there are a total amount of 1201 km of primary roads and 10.825 km of secondary roads. Their distribution is showed then.

Figure 6: Road network of Catalonia. Source: IEFC.

7.2 Plan for Energy and Climate Change Catalonia 2012-2020 (PECAC)

PECAC's objective is clear: to achieve an economy and a society of low intensity and low carbon energy, innovative, competitive and sustainable in the medium and long term.

The PECAC proposes for the first time and in a coordinated way the energy policy and climate change, incorporating estimates of greenhouse gas emissions and adapting to the fulfilment of the European objectives in these areas.

Overall savings in terms of primary energy			
	Year 2020		
	Base consumption (ktep)	Savings	
		ktep	%
Industry	5331,7	924,9	17,3
Transport	6846,5	1418,2	20,7
Domestic	2958,4	593,4	20,1
Services	2269,3	373,7	16,5
Primary	673	117,1	17,4

Table 4: Overall savings of primary energy. Source: PECAC.

Catalonia fixes a very ambitious target in renewable energy to meet the commitments of the European Union. The savings and energetic efficiency policies plan to reduce 20,20% of Catalonia energy consumption in 2020, fulfilling the target set by the EU.

In the same line, it is also expected to achieve savings of 3437,30 ktep in energy consuming sectors in 2020, and an improvement in final energy intensity of 1,87% by year.

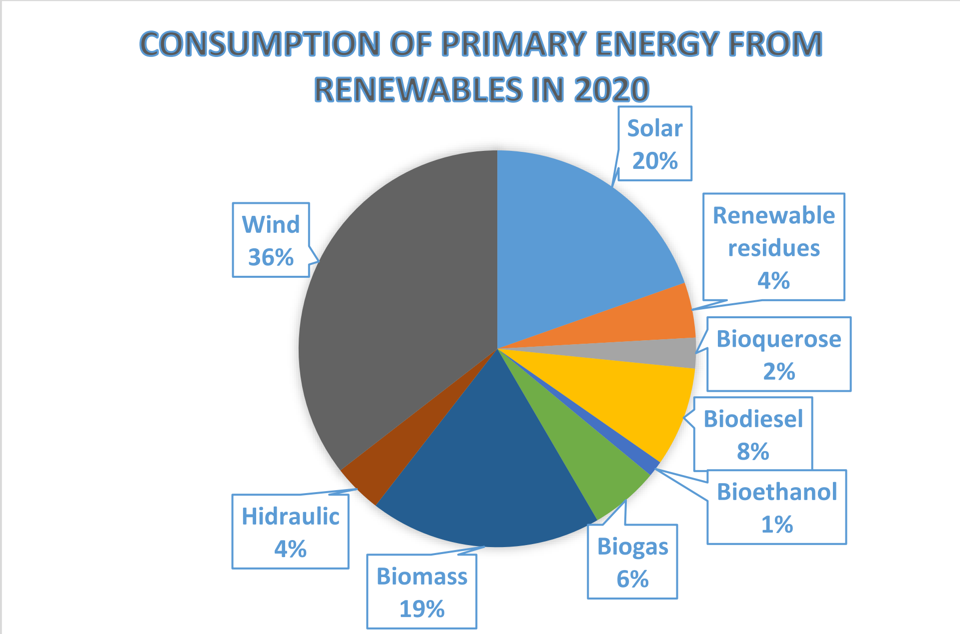

Chart 5: Consumption of primary energy from renewables in 2020. Source: PECAC.

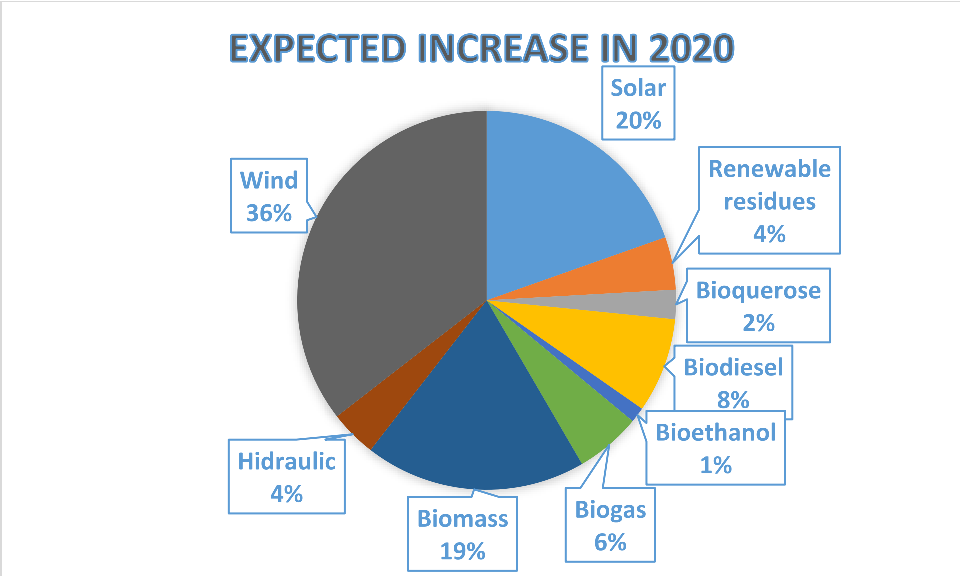

Chart 6: Expected increase in consumption of primary energy from renewables in 2020. Source: PECAC.

One of the main areas of responsibility will be forest biomass agriculture. It will be developed a new forest policy to take advantage of the forests energetic power. This will reflect the new Territorial Plan of Catalonia Forest that will carry out policies to support the biomass sector (advice, specific grants, R & D, training, administrative simplification ...) to promote their production, processing and use.

7.3 Public and private agents involved

In Catalonia there are a large number of public and private agents involved in the study, control, promotion and sale of services based on the generation of energy with biomass. These agents form a network of relevant actors for the operation of current and future biomass experiences. The results disseminated from the experiences promoted by companies and public entities facilitate the generation of new initiatives with the same objectives.

Public entities		
Generalitat de Catalunya, Departament de MediAmbient i Habitatge		
Generalitat de Catalunya, Departamentd'Agricultura, Alimentació i Acció Rural		
Generalitat de Catalunya, Departament de Política Territorial i Obres Públiques		
Diputació de Barcelona, Xarxa de Municipis		
InstitutCatalà de l'Energia (ICAEN)		
Centre Tecnològic i Forestal de Catalunya (CTFC)		
Centre de Recerca Ecològica i AplicacionsForestals (CREAF)		
Consorci Forestal de Catalunya (CFC)		
Private entities		
Recuforest S.L.	Ecoenergia S.A.	Ambigest
GrupCassà	MolinsEnergia S.A.	TermisaEnergia S.A.
Tradema, GrupTafisa	Energia Natural de Móra S.L.	Nova Energia, S.L.
Calderas, L.Solé-S.A.	Tratamiento y Valorización de Residuos S.A.	AvamsolarBiomassa
ConstruccionesCorma S.A.	Tractament y revalorització residusMaresme, S.A.	EnergrupBio-renovables S.L.
Pirobloc S.A.	Trama Tecno Ambiental S.A.	Gahelios
Grefer, S.L.	Recalor S.A.	Sapre
Ibersilva	Serinsaenergia i mediambient S.A.	SoliClima

Table 5: Catalan organizations and companies referring to the energy use of biomass. Source: PECAC.

Catalonia has in operation 16 biomass energy production facilities, mostly thermal production. Most installed boilers consume less than one thousand tons each year of fuel and are destined for residential heating. The most important ones (more biomass consumption) are described below.

Firstly, in Mora de Ebre (province of Tarragona) a gasification plant with electricity production from almond shells (500 kWe) is in operation. The facility consumes 2150 tons of biomass, similar to the one that is produced at the central heating plant located in the municipality of Molins de Rei (Barcelona province), in the urbanization "La Granja".

Moreover, the thermal plant of Sant Pere de Torelló (Province of Barcelona) consumes 5.000 Mg/year of biomass, in order to expand its heat production and biomass consumption up to 45000 Mg / year. In Solsona (province of Lleida) stands out a heat production plant with an annual consumption of wood processing residues of almost 30.000 Mg.

Finally, the newest energy production plants situated in Senia and Garriga have an annual consumption of 70.000 and 60.000 Mg of wood respectively.

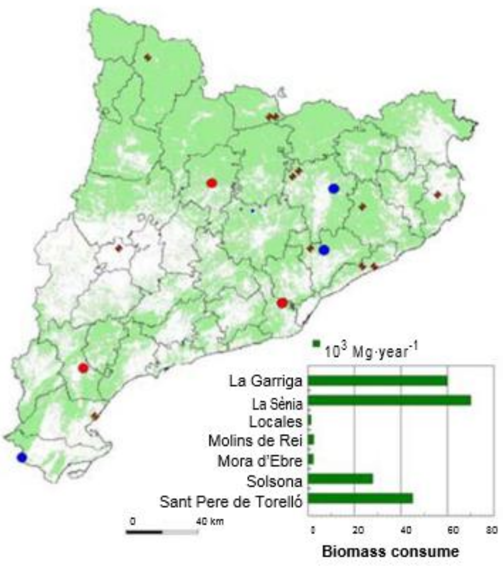

Figure 7: Plants of biomass energy generation in Catalonia. Source: PECAC.

7.4 Current situation in Catalonia

The forests in Catalonia cover about 1.2 million hectares, about two-thirds of the forest area and 40% of the total land. This area has been gradually increased due to the abandonment of agricultural land and afforestation of crops. So have standing stock in significant quantities according to forest inventories, so that forest area and standing volume are progressively increasing.

In order to seize the opportunity of forest, socio-economic and energy development that bioenergy implies, the Government of Catalonia adopted in February 2014 a strategy to promote the use of forest and agricultural biomass for heating purposes, by coordinating the actions of four departments. This strategy addresses the sector from a global perspective. Among others, the strategy proposes that all ongoing measures are to be coordinated under a Single Program for Economic Grants (PUAE, ProgramaÚnicd'AjutsEconòmics), including non-repayable grants and credit financing.

The Barcelona Provincial has funded several installation projects in facilities across the province, which in many cases have attracted private investment and resulted in actual installations. Besides this, they have opened a call for grants for the installation of biomass boilers in protected natural areas. The Girona Provincial Council is subsidizing biomass boilers in buildings of the municipalities that have signed the Covenant of Mayors. The Lleida Provincial Council is subsidizing investments in energy efficiency.

This growing interest in biomass thermal heating for buildings has caused a significant increase in the number of small and medium sized biomass boilers (operating with pellets or fragments), causing the birth of an industry that was virtually nonexistent in Catalonia.

Biomass consumption (ktep/year)	2003	2010	2015	**Variation 2003-2015**	**Variation 2003-2015 (%)**
Agricultural and forestry biomass	93,9	180,9	278,6	184,7	196,7

Table 6: Evolution of primary energy consumption with biomass in Catalonia. Source: PECAC.

It has been increased the number of companies that are dedicated to the manufacture, distribution and installation of biomass boilers and it has been promoted pellet production plants of which several are in operation.

However, the data consumption of biomass and forest based agricultural Catalonia indicate that there is a situation of delay in relation to the objectives set in the Energy Plan of Catalonia 2006-2015.

This situation has been provoked on the one hand by the financial crisis that has affected the financing of many projects in promotion and development, and on the other by the fall in fossil fuel prices experienced in 2008 and 2009. In this sense, we can consider that the amount of existing biomass boiler installations is still very small compared to the total existing potential and consequently biomass consumption is also very low.

Apart from this facts that have slowed the growth of the sector, it has to be considered the main obstacles to the implementation of technologies for energy use of forest biomass: the lack of economic profitability and the existence of logistical and supply problems.

The first one is a consequence of the existence of inefficiencies in the timber market, the high degree of fragmentation of property (lack of partnerships) and the existence of a weak Forest Policy.

The second one is due to that currently there is practically no one in Catalonia who has a procedure that allows to transform forest biomass into a consumable product for the facilities, nor that it can give a guarantee of supply.

7.5 Consequences current situation and recommendations

This obstacles to the implementation of technologies for energy use of forest biomass have created the following situation in the woods of the country:

- Great accumulation of fuel in the woods due to the low forest exploitation
- Method of harvesting that, during years, has only extracted the bigger and good trees.
- Great presence in the forest of little trees and lack of trees of big diameter
- Lack of inversion in the forests: trails, etc.

Clearly, it is needed a new forest policy in Catalonia, which has as one of its mainstays the energy use of forests, and should be reflected in the new Territorial Plan of Catalonia Forest.

The strategy that has to be implemented in the field of forest biomass has to achieve the following objectives based on specific areas:

- Advice for the evaluation of biomass resource to those emerging initiatives, assess the sites available (firewood, cork, bananas, poplar).
- Promotion of specific biomass grants.
- Lines of R & D, both in the stages of production of the resource as energy transformation.

- Dissemination, seminars and training to the various stakeholders in the sector.
- Guarantee the supply chain of forest biomass for energy production.
- Maintenance of aid lines to reduce the extraction cost of forestry residual biomass.
- Coordination of the competent authorities in the energy use of biomass.
- Promote the biomass heating and electrical installations of forest biomass.

Furthermore, in order to implement this strategy, the competent authorities (public and private as shown in point 9.3) and the potential target group (Forest technicians, managers and owners, potential deliverers, investors) on energy use of biomass should be coordinated.

It is important to clarify that it is not only a question of taking advantage of existing biomass surpluses in forests, but of making long-term planning. It should be planned how to combine all possible uses of wood.

7.6 Conclusions drawn after the analysis

The conclusions that derive from the analysis of the current biomass situation in Catalonia are the following:

- The main obstacles in the implementation of the technologies of energy utilization of forest biomass are the uncertain and limited economic profitability and the problems in the logistics and guarantee of the supply.
- The accumulation of biomass in the forests of Catalonia can increase the risk and danger of fires, which should be taken into account in energy recovery studies.
- There are inefficiencies in the timber market, a high degree of fragmentation of forest ownership (lack of partnerships) and a weak Forest Policy.
- The forest areas of Catalonia are environmentally and socially diverse. The social agents and the natural characteristics of the territory are those that must determine which management model is the most appropriate.
- It is necessary to increase the knowledge about the techniques and machinery necessary for the extraction of the biomass for its energetic use.
- The energy use of forest biomass must respond to a global energy, environmental and social strategy.

- The economic profitability of forest biomass utilization projects should include the environmental costs of doing nothing in the forest.

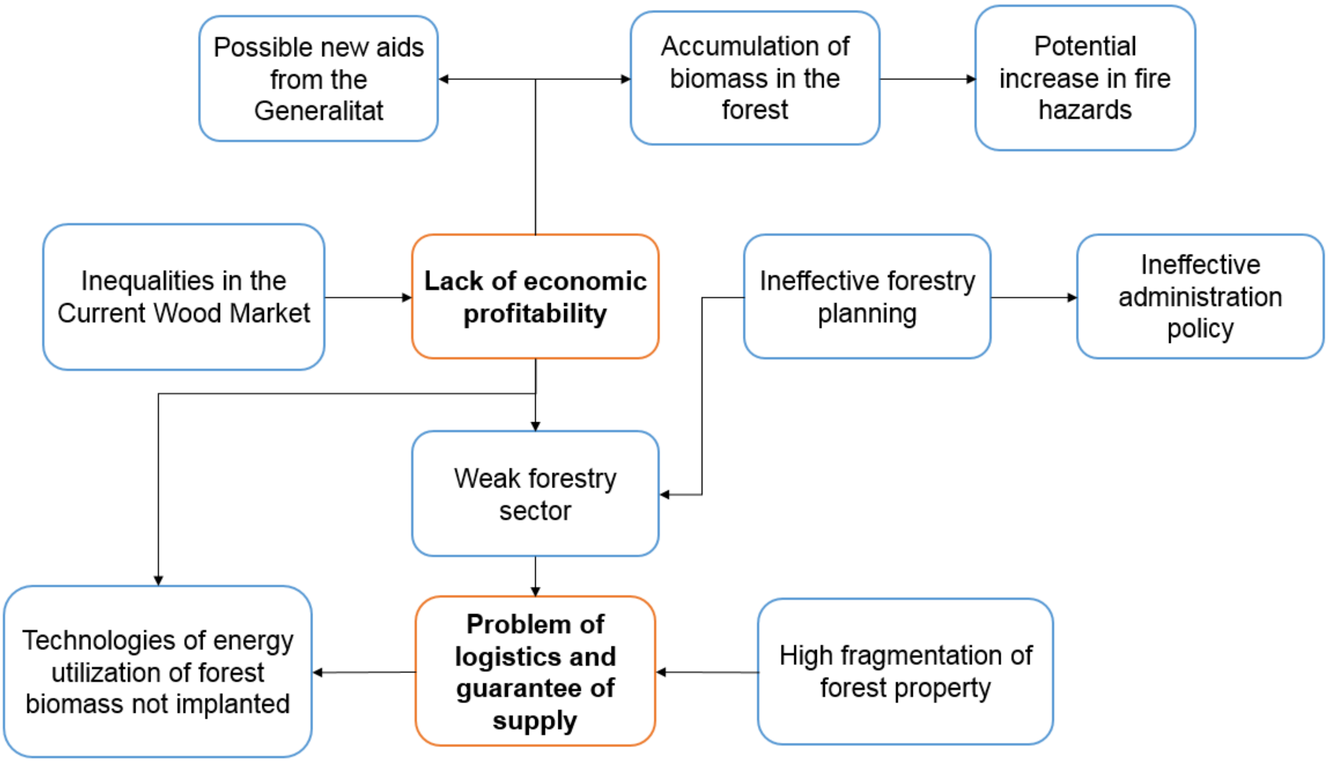

Figure 8: Cause-effect relationships of forest biomass in Catalonia. Source: self-made.

8. Analysis and determination of supply chain best location

After analysing the current situation in Catalonia, a clear justification of the project can be seen. That is why given the scope of this project, it will be focused on trying to solve the implementation of the supply chain in the most suitable location.

8.1 Methodology: Comparative analysis

In order to study the feasibility of the different options, it has been decided to do a comparative analysis that allows us to evaluate quantitatively according to the main criteria chosen, which location presents greater suitability. This analysis is divided into several steps that are described below:

1. Obtaining criteria: for the evaluation of an alternative solution to the problem, can be quantitative or qualitative.

2. Assignment of weights to each criterion: factor weights on a scale of 1 to 10 so that those considered to be of greater importance (1 means unimportant and 10 essential) weigh more in the model.

3. Analysis and weighting of alternatives: it analyses each of the locations according to the chosen criteria and is weighed according to its level on a scale of 1 to 5 (1 means little beneficial and 5 a lot).

4. Choose option: multiplying the weight of each criterion evaluated in each location by its previously defined weight and total sum to choose the most optimal option.

The purpose is to investigate a number of alternatives based on multiple criteria. The difficulty lies in establishing which criteria are critical and at the same time what is the importance or weight of each one of them.

8.2 Choice of areas with forest biomass potential

A series of populations have been chosen on which a small study has been done to promote the application of forest biomass as an energy source in Catalonia.

These have been chosen because they are important because they have forest, or they have high unemployment rates and because they are representative of the different singularities of the Catalan territory.

Therefore, the areas considered in our study as areas with great potential for forest biomass are the following: Gironès, Anoia, Solsona, Noguera, Ribera del Ebro and Priorat.

Figure 9: Areas with forest biomass potential. Source: self-made.

8.3 Identification and weighting of criteria

Once the areas with higher forest resources have been defined, each criterion or factor must be characterized, identifying it with a quantitative measure that allows us to make a comparative analysis.

The energy criteria that we are going to take into account in the selection of optimum areas for the extraction of forest biomass are the following:

Biomass available: It is the most important factor, it is to have the greatest possible amount of forest resources, since this is usually much dispersed and does not possess a high density [Ha].

Close to important urban centres: Approximate distance between the area of extraction of the raw material to the population or nearest major city where the plant will be installed. The distance is calculated by road [km].

Communication by road: A good communications infrastructure means a reduction in the cost of energy and increases the area accessible for the collection of the raw material. It is determined according to the quality of the roads (Good, Fair, Bad) between the nearest important urban centre and the approximate centre of the forest area of the studied area.

Concentration biomass plants: Number of Biomass Plants in operation in the surroundings, penalizing those alternatives that have more plants in their surroundings, as this can decrease the amount of available raw material.

Slope of the terrain: Factor that influences the extraction of the forest resource, since it implies the use of machinery increasing the cost of extraction. Earlier than 50%, the use of the resource is no longer profitable. Since it is very difficult to determine the average slope of a terrain, it will be done from its average altitude [m].

CRITERION	WEIGHT
Available biomass	10
Proximity towns	7
Communications Infrastructure	8
Nearby other biomass plants	9
Slope terrain	6

Table 7: Weight of each criterion. Source: self-made.

8.4 Evaluation criteria in different locations

Below is the value of the different criteria for each of the alternatives from which to choose.

Available biomass: Direct scale weighting (greater forest area, better result). Unit: hectares.

[Ha]	[0, 20000]	[0, 40000]	[0, 60000]	[0, 80000]	[0, 100000]
	1	2	3	4	5

Table 8: Ponderation available biomass. Source: self-made.

AVAILABLE BIOMASS	Total surface [Ha]	Forestry surface [%]	Total forest area [Ha]	Weighing
Noguera	178400	53%	94552	5
Gironès	57500	63%	36225	2
Anoia	86600	54%	46764	3

Ribera d'Ebre	82700	60%	49620	3
Solsonès	100000	73%	73000	4
Priorat	49800	67%	33366	2

Table 9: Biomass available. Source: Technical report on agricultural holdings in Catalonia.

Proximity towns: Reverse scale weighting (closer proximity, higher result). Unit: kilometers.

[Km]	[0, 10]	[0, 20]	[0, 30]	[0, 40]	[0, 50]
	5	4	3	2	1

Table 10: Ponderation by distance. Source: self-made.

PROXIMITY TOWNS	Nearby population	Distance[km]	Weighing
Noguera	La Noguera	32	2
Gironès	Girona	22	3
Anoia	SantBoi de Llobregat	25	3
Ribera d'Ebre	Amposta	47	1
Solsonès	Solsona	36	2
Priorat	Reus	37	2

Table 11: Distance to urban centres. Source: Google Maps.

Communication infrastructure: Direct scalar weighting (higher quality, better result).

Quality	Bad	Regular	Good
	1	3	5

Table 12: Ponderation by communication infrastructure quality. Source: self-made.

COMMUNICATION INFRASTRUCTURE	Highway	Quality	Weighing
Noguera	C-13/C-147a	Good	5
Gironès	GIV-6641/C-65	Bad	1
Anoia	BV-2411/ BV-2041/C-32	Regular	3
Ribera d'Ebre	C-12	Regular	3
Solsonès	L-401/C-26	Regular	3
Priorat	TV-7041/C-37/C-14	Good	5

Table 13: Quality of road communication. Source: Google Maps.

Number of plants close: Reverse scale weighting (the higher the number of plants, the worse the result).

Number of plants	0	1	2	3	4
	5	4	3	2	1

Table 14: Ponderation by number of plants. Source: self-made.

OTHER BIOMASS PLANTS	Number of plants	Weighing
Noguera	4	1
Gironès	2	3
Anoia	3	2
Ribera d'Ebre	1	4
Solsonès	2	3
Priorat	1	4

Table 15: Number of biomass plants. Source: IDESCAT.

Slope terrain: Reverse scale weighting (higher slope, worse result).

[m]	[0, 140]	[0, 280]	[0, 420]	[0, 560]	[0, 700]
	5	4	3	2	1

Table 16: Ponderation by altitude. Source: self-made.

SLOPE TERRAIN	Average altitude [m]	Weighing
Noguera	567	1
Gironès	70	5
Anoia	313	3
Ribera d'Ebre	233	4
Solsonès	670	1
Priorat	364	3

Table 17: Average altitude. Source: Technical report on agricultural holdings in Catalonia.

8.5 Results and final decision

Once it has been defined each weight in each territory for all criteria it is time to do the last step: multiply the weight of each criterion evaluated in each location by its previously defined weight and do the total sum. The results are showed below:

ZONE	AVAILABLE BIOMASS	PROXIMITY TOWNS	COMMUNICATIONS INFRAESTRUCTURE	NEARBY OTHER BIOMASS PLANTS	SLOPE TERRAIN	TOTAL PUNTUATION
Noguera	50	14	40	9	6	119
Gironès	20	21	8	27	30	106
Anoia	30	21	24	18	18	111
Ribera d'Ebre	30	7	24	36	24	**121**
Solsonès	40	14	24	27	6	111
Priorat	20	14	40	36	18	**128**

Table 18: Comparative analysis results. Source: self-made.

As it can be seen, the region that gets a higher score is the Priorat.

However, despite initially it was only considered the choice of a single territory, it is decided to study jointly the regions of Ribera d'Ebre and Priorat given the proximity and the high result of both in the comparative analysis.

This decision gives a clear advantage: optimization of the territory as well as the forest biomass resources and main consumers.

8.6 Sensibility analysis

The comparative analysis is a very powerful tool that allows you to quantitatively evaluate which option is the most optimal depending on certain criteria. However, this analysis has a clear defect: subjectivity when weighing the criteria.

In order to eliminate this subjectivity, a sensitivity analysis has been carried out where the criteria will be weighted in the limit cases so as to see how our system responds. The critical factors will be scored with the highest score and the remaining with the minimum of the 10.3 table (10 and 6 respectively).

In the first case, it will be prioritized the first part of the supply: the availability and accessibility of the biomass. The following tables show the weighting of the criteria and the final result:

CRITERION	WEIGHT
Available biomass	**10**
Proximity towns	6
Communications Infrastructure	6
Nearby other biomass plants	6
Slope terrain	**10**

Table 19: Weight of each criterion in the first case of the sensibility analysis. Source: self-made.

ZONE	AVAILABLE BIOMASS	PROXIMITY TOWNS	COMMUNICATIONS INFRAESTRUCTURE	NEARBY OTHER BIOMASS PLANTS	SLOPE TERRAIN	TOTAL PUNTUATION
Noguera	50	12	30	6	10	108
Gironès	20	18	6	18	50	112
Anoia	30	18	18	12	30	108
Ribera d'Ebre	30	6	18	24	40	**118**
Solsonès	40	12	18	18	10	98
Priorat	20	12	30	24	30	**116**

Table 20: Comparative analysis results in the first case of the sensibility analysis. Source: self-made.

In the second case, the second part of the supply chain will be prioritized: the proximity of the populations as well as the infrastructure of the communications to access them. The following tables show the weighting of the criteria and the final result:

CRITERION	WEIGHT
Available biomass	6
Proximity towns	**10**
Communications Infrastructure	**10**
Nearby other biomass plants	6
Slope terrain	6

Table 21: Weight of each criterion in the second case of the sensibility analysis. Source: self-made.

ZONE	AVAILABLE BIOMASS	PROXIMITY TOWNS	COMMUNICATIONS INFRAESTRUCTURE	NEARBY OTHER BIOMASS PLANTS	SLOPE TERRAIN	TOTAL PUNTUATION
Noguera	30	20	50	6	6	112
Gironès	12	30	10	18	30	100
Anoia	18	30	30	12	18	108
Ribera d'Ebre	18	10	30	24	24	**106**
Solsonès	24	20	30	18	6	98
Priorat	12	20	50	24	18	**124**

Table 22: Comparative analysis results in the second case of the sensibility analysis. Source: self-made.

Una vez realizado en análisis de sensibilidad se puede observar que nuestro sistema responde favorablemente a las situaciones críticas. Ribera d'Ebre y Priorat siguen siendo las que máxima puntuación obtienen. Solo en el segundo caso Ribera d'Ebre tiene una puntuación inferior a otras zonas.

Once the sensitivity analysis has been performed, it can be observed that our system responds favorably to critical situations. Ribera d'Ebre and Priorat are still the ones that have the highest scores. Only in the second case Ribera d'Ebre has a lower score than other areas.

Therefore, having a robust system in front of possible changes in the weighting of the criteria, the choice of the implementation of the logistics chain in the Ribera d'Ebre and Priorat areas can be considered as good, since the introduced subjectivity has been eliminated.

9. General description of the chosen regions

9.1 Location and municipalities

The study area are 17 municipalities that are shown in the next table, belonging to the regions of Priorat and Ribera d'Ebre.

Priotat	Ribera d'Ebre
Bellmunt del Priorat	Benissanet
Capçanes	Garcia
Falset	Ginestar

Guiaments	Miravet
Marçà	Móra d'Ebre
Masroig	Móra la Nova
Molar	Rasquera
Pradell de la Teixeta	Tivissa
Torre de Fontaubella	

Table 23: Regions and municipalities in the field of study. Source: self-made.

Priorat is a region located in the heart of the pre-coastal mountains, halfway between Camp de Tarragona and Terres de l'Ebre. It is a region with a relief very injured and it is bordered by fairly high mountains.

The region of Ribera d'Ebre extends over 40 km on both sides of the river Ebro in its entrance in Catalonia.

The study area has a population of 21,557 inhabitants. Mora d'Ebre is the capital of the region of La Ribera d'Ebre and the most populous city in the area of study with almost 5,800 people (representing 26.9% of the population of the study area). Here comes Mora la Nova with almost 3,300 inhabitants (15%) and Falset, the capital of Priorat, with almost 3,000 inhabitants (13.6%).

The population density in the study area is 34.9 inhabitants / km2, where the highest density occurs in Mora la Nova with 203.3 inhabitants / km2 and the lowest density is found in Tivissa with 8.6 inhabitants / km2 (IDESCAT, 2011).

The 94% of the population live in small towns (agglomerated population), while the remaining 6% does in scattered houses (sparsely populated).

The 87% of all major field of study have heating system, being the most used fuel oil (34%) and electricity (22%). Wood (in the form of firewood, mainly) represents only 0.1% of the total heating fuel.

9.2 Forest area distribution

The landscape of the study area is characterized by large areas of agricultural crops in the middle, surrounded by forest area.

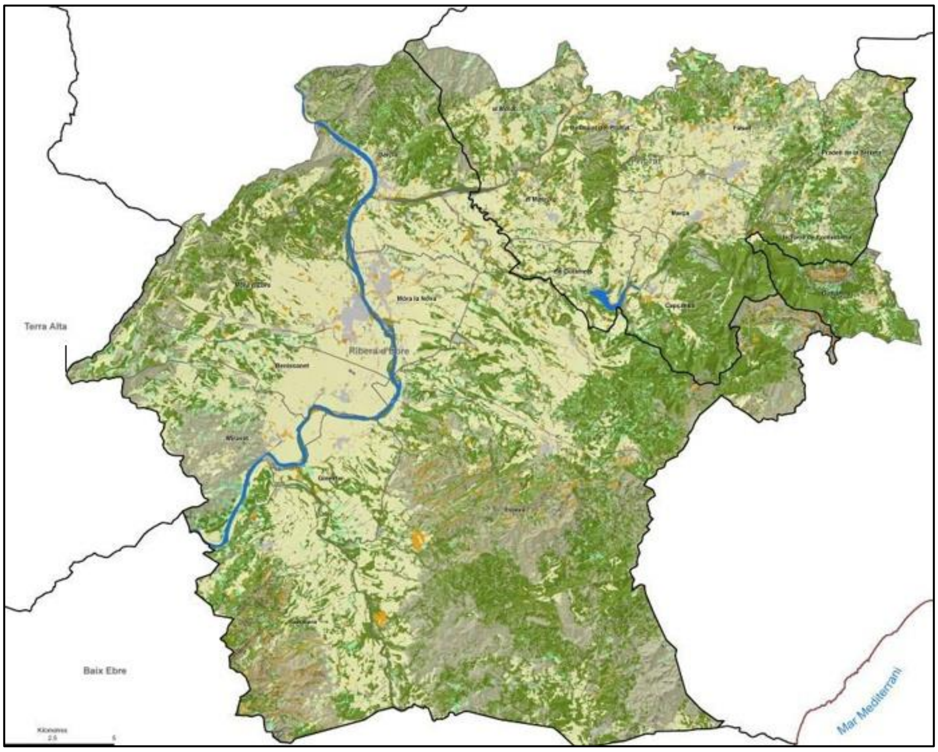

Figure 10: Land cover of the study area. Source: IDESCAT.

Of the 61,829 ha of the study field, almost 42,000 ha (67% of the surface) correspond to forest land, 18,300 ha (30%) to crops and 1200 (the remaining 2%) to unproductive artificial (urban areas).

Of the nearly 42,000 ha of forest land that is in the field of study, 23,000 ha (55%) own to forests (20,000 hectares of which are dense forests), 16,000 ha (38%) are thickets, and 1,700 ha (4%) are meadows and pastures.

9.3 Fire risk

One important thing that has to be taken into account at the time of developing the supply chain is the fire risk. It has to be remembered that one of the principal advantages of developing biomass as an energy resource is the capacity for avoiding fires. Consequently, it has to be tried to take advantage of the resources of all the potentially dangerous areas of a fire to avoid them.

The forest fire risk map is elaborated taking into account historical factors fire, the type of vegetation, the topography and climate.

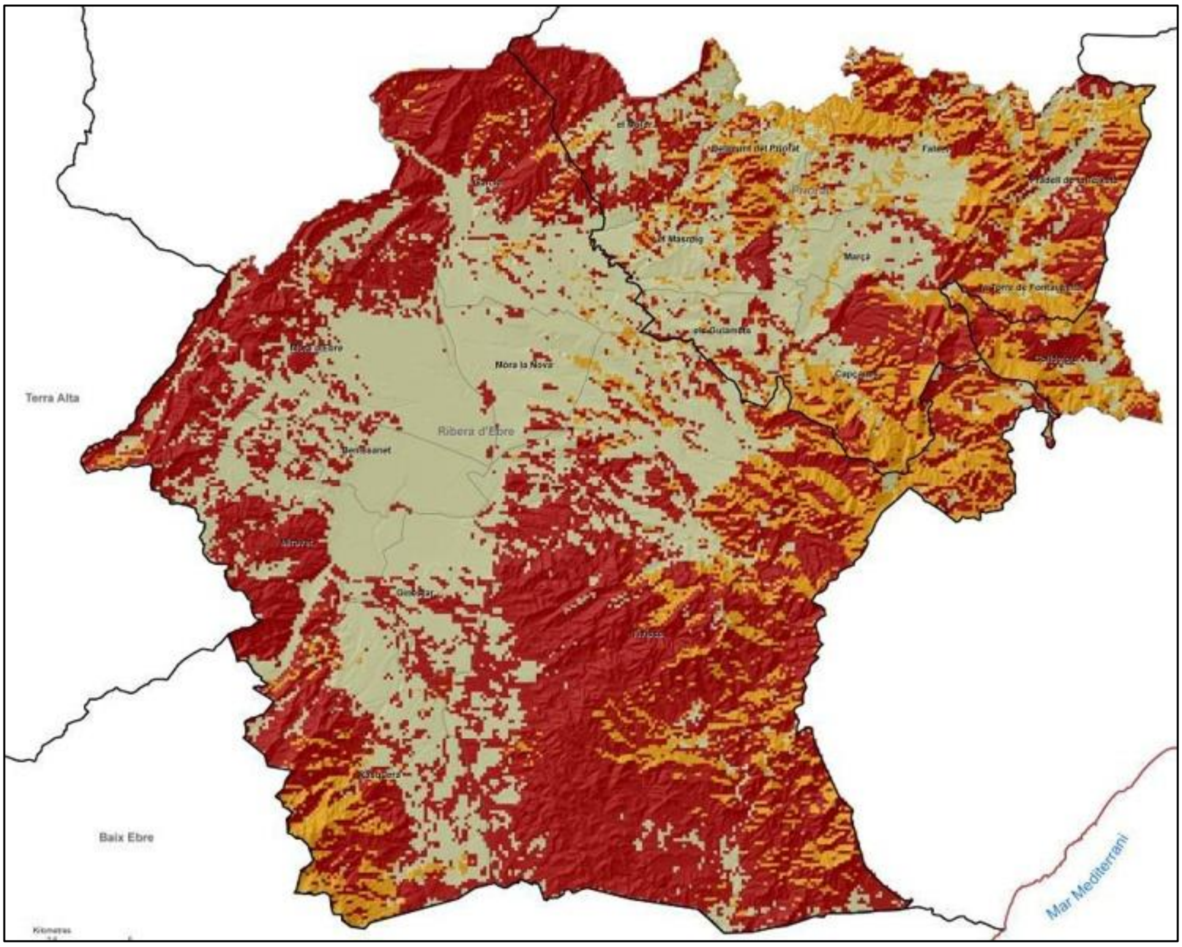

Figure 11: Fire risk in the study area. Source: DMAH

According to DMAH, the 64% of the surface area of study is considered high risk area fire high or very high.

Fire risk	Area (%)
Low	36
High	16
Very high	48

Table 24: Area according to fire risk. Source: DMAH.

9.4 Road network

The road network, its slope and its state can influence the cost of use. It mainly depends on the distances for extract the resources, the kind of machinery that can access and time travel. In this way, insufficient good conditions of the road network can leave areas with a high potential of resources without any use.

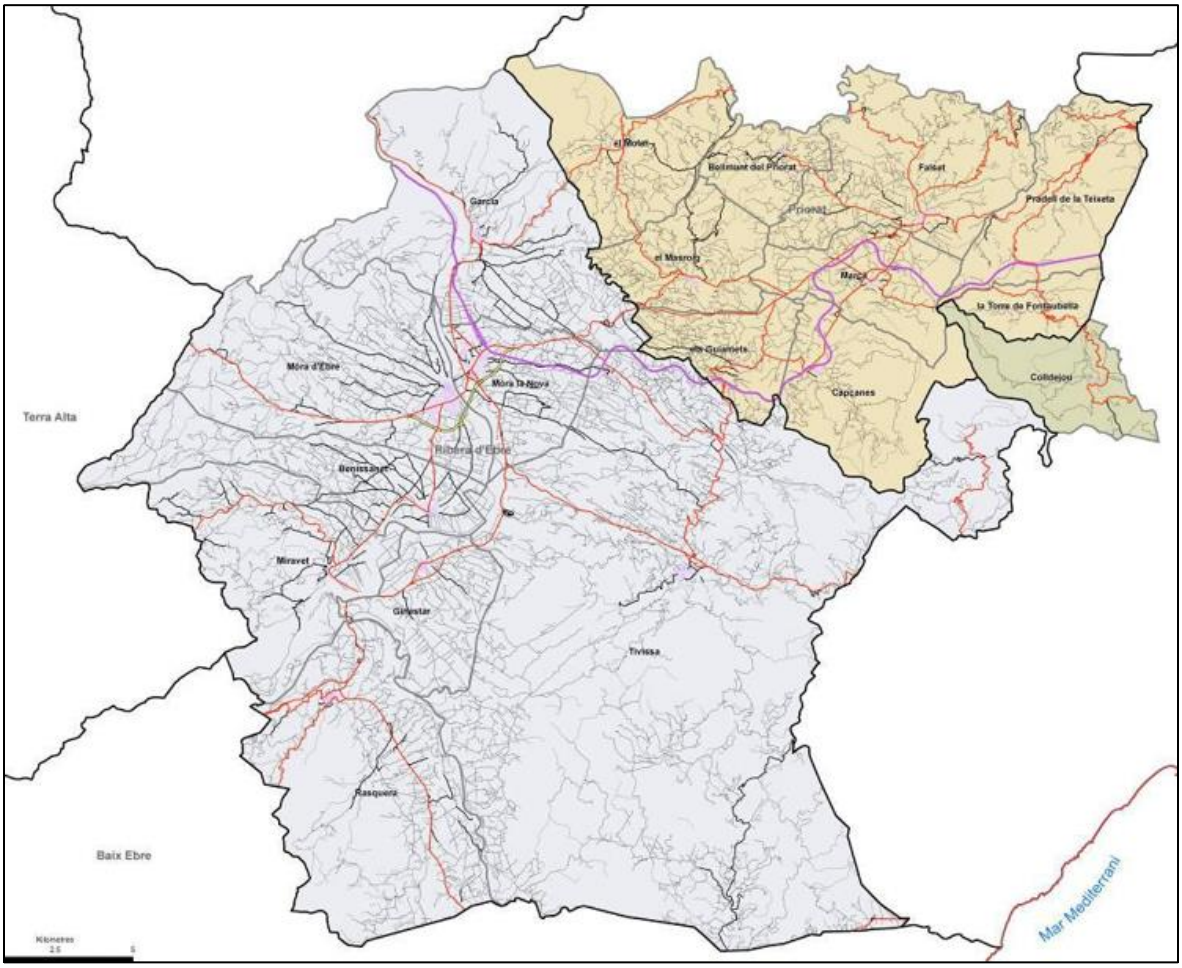

Figure 12: Road network in the study area. Source: ICC.

The next table shows the existing road density in the study area, to get a rough idea of the level of roads in relation to the forest area. It can be seen that the mainly type of road that involve the road network of the supply chain is the rural roads.

Type of road	Road density (m/ha)
Primary net	14,3
Secondary net	11,0
Rural roads	145,8
Others	10,1

Table 25: Density of forest roads in the study area. Source: ICC.

10. Forest biomass quantification

10.1 Forestry resources

Of the 41,800 that correspond to forest land, 48% of them belong to the category of dense woodland, while 38% are thickets.

Surface type cover	Area	
	ha	%
Bright wooded	2983	7,1
Dense wooded	20190	48,3
Unproductive natural	937	2,2
Thickets	15984	38,2
Meadows and grasslands	1716	4,1
Total	41811	

Table 26: Distribution area of forest cover. Source: CREAF-MCSC.

It is important to clarify that it is only going to be considered in the biomass quantification the main species of the dense wooded area. Those are the ones that represent more than 2% of the total forest area.

Species	Dense wooded area	
	ha	%
Arbutus unedo	11	0,1
Pinus halepensis	17634	87,3
Pinuss ylvestris	18	0,1
Pinus nigra	220	1,1
Pinus pinaster	5	0
Platanussp	2	0
Populussp	4	0
Quercus faginea	124	0,6
Quercus ilex	1890	9,4
Quercus pubescens	8	0
Other caducifolis	16	0,1

Table 27: Forest area of dense woodland. Source: AFIB-CTFC from CREAF-MCSC.

Thus, the study is going to be developed in the main species: pine (Pinushalepensis) and holm oak (Quercus ilex). In addition, the following differentiation is made regarding the availability of biomass:

- Maximum available biomass (total BFP): Primary forest biomass taking into account all trees.

- Minimum biomass available (small BFP): Primary forest biomass of small trees (CD <20 cm) and large tree canopies (CD> 20 cm).

10.2 Calculation considerations and results

From a standpoint of use execution, only the forests that meet the following requirements are considered accessible:

- Fraction of covered cover greater than 70%, in order to guarantee the stability of the soil against erosive processes and favor the growth of the mass.
- Maximum distances to the roads depending on the slope, due to accessibility restrictions of the mechanization:
    - Slope <30% at a maximum distance on roads of 400 m.
    - Slope between 30 and 60% at a maximum distance of 75 m.
    - Slope between 60 and 100% at a maximum distance of 35 m.

The accessible surface is calculated taking into account the abovementioned accessibility restrictions (slope and maximum distance to the track). For the ecological restrictions (FCC> 70%), the woodland area (FCC> 20%) of the third edition of the Map of Land Cover of Catalonia (CREAF, 2005-2007) was crossed with the capitalized area > 70%) of the Forest Map of Spain in Catalonia (DGB, 2000-2001).

Therefore, the accessible surface is 12.918 ha (66,2%) with respect to the total area of wooded forest.

Specie	Wooded area (ha)	Accessible area (ha)	% accessible
Pinus halepensis	17.634	12.075,6	68,5
Quercus ilex	1.890	842,2	44,6
Total	**19,524**	**12.918**	**66,2**

Table 28: Accessible area. Source: AFIB-CTFC through CREAF and DGB.

The calculation of available biomass has been made from average values of carpenter volume with bark, volume of fatwoods and annual net increase per hectare of the Third National Forest Inventory (IFN3) and the Forest Ecological Inventory of Catalonia (IEFC) of Solsonès (CREAF-DMAH, 2011), taking into account the accessible area (CREAF-MCSC, 2005-2007 and DGB, 2000-2001).

Taking into account all these considerations, the biomass available in the field of study is 810.045 m^3 and the biomass of small trees 344.489 m^3.

Specie	Total BFP (m^3)	BFP-smalls (m^3)
Pinus halepensis	710.572	242.834
Quercus ilex	99.473	101.655
Total	**810.045**	**344.489**

Table 29: Volume of available biomass in the area of study. Source: AFIB-CTFC through CREAF-DMAH, CREAF-MSCS and DGB.

Although the m_3 is a unit that is part of the international system of units, when it is talked about bioenergy terms, instead of the m_3 itis used the unit of tone at 30% in humid base (t_{30}). The following table shows the quantification of forest biomass in this unit.

Specie	Total BFP (t_{30})	BFP-smalls (t_{30})
Pinus halepensis	468.978	160.270
Quercus ilex	104.447	106.738
Total	**573.424**	**267.008**

Table 30: Tones in 30% humid base of available biomass in the area of study. Source: AFIB-CTFC through CREAF-DMAH, CREAF-MSCS and DGB.

11. Logistics of forest biomass supply

Although the use of pellet can be a good alternative in low-power facilities with little space for storage and equipment placement, the use of the sliver is more profitable in large buildings such as scattered housing, public facilities such as pavilions, swimming pools and schools, establishments of services such as hotels, rural tourism houses and campsites, farms and industries. That's why it has been determined to use slivers instead of pellets in the logistics of forest biomass supply.

The logistic process of the sliver comprises the following phases:

1. Harnessing: clearing and unpacking the tree.
2. Processing: slivering in track or plant.
3. Transport: depending on where the material is processed, transport is of the sliver or of the tree.

4. Storage: optionally of the tree and usually of the sliver.
5. Supply of the sliver.

Harnessing includes from tree cutting to transport to the storage site (called a warehouse or yard) and the supply includes transporting the slivers from the yard to the customers' point of consumption.

Splinter production systems depend mainly on slivering. Depending on the time of the chain where it is made, the operating system differs. The most common are slivering on track or loader and slivering to patio, and there may be a third option, to plant, in specific cases of plants with large consumption, such as power generation or cogeneration.

The selection of one or the other system is made according to various physical and economic factors. The most important are: characteristics of the biomass, location and characteristics of the terrain, distance to be travelled, road network status and volume of sliver to be produced.

In the following scheme can be seen the process of utilization and supply of primary forest biomass in the form of slivers.

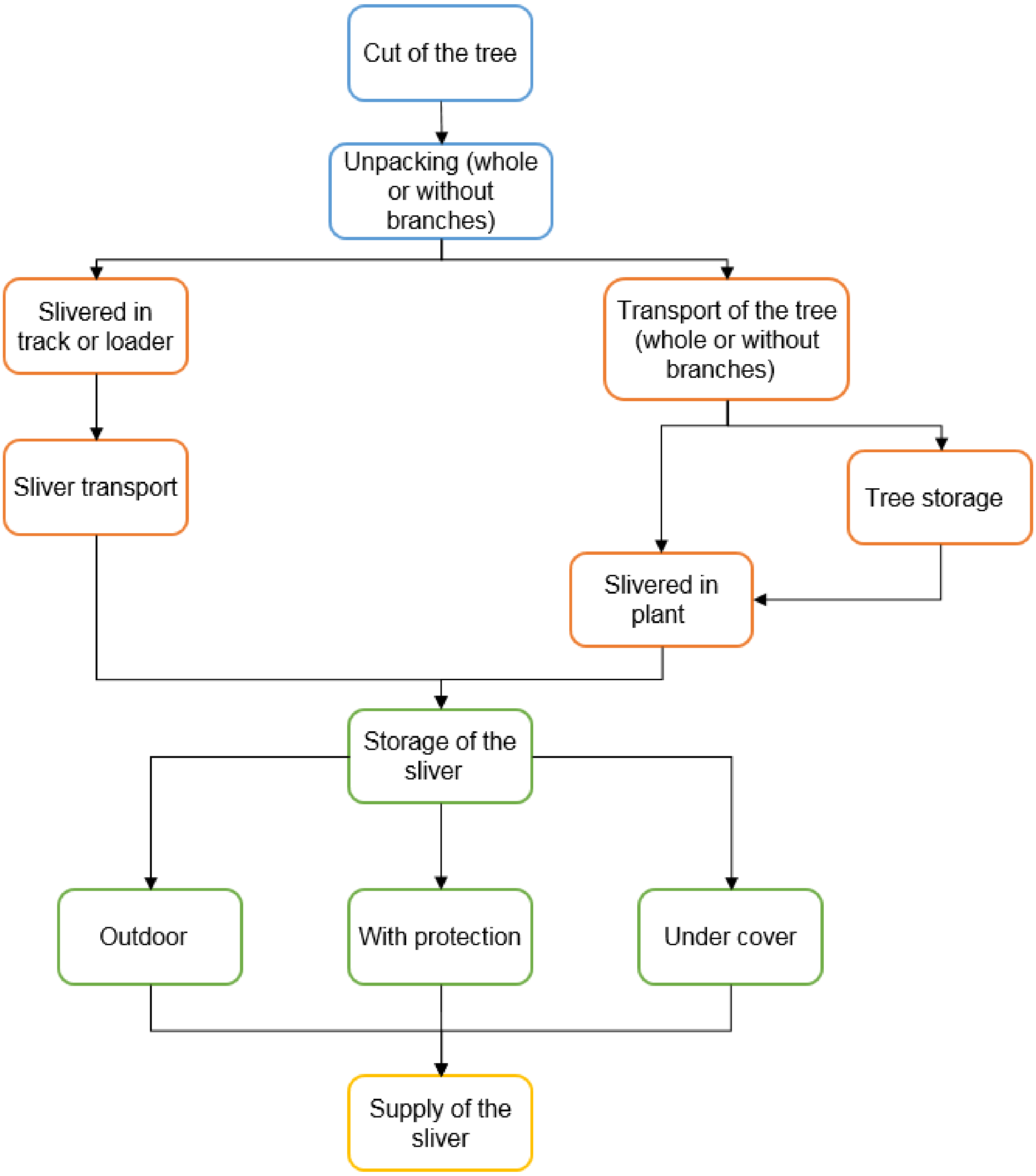

Figure 13: Scheme of the process of utilization and supply of primary forest biomass in the form of slivers. Source: AFIB-CTFC.

11.1 Harnessing

The objective is to obtain the maximum possible amount of forest biomass leaving the maximum amount of twigs on the ground to avoid part of the extraction of nutrients and, at the same time, to reduce costs.

However, the valuation of removing branches or not depends on the requirements of the installation in terms of acceptance of chlorine and alkaline metals contained in the branches.

For the cut, the mechanical or processing saw is used basically, and the work is done by means of tractor with winch, skidder or autoloader

11.2 Processing and transport

For the production of sliver it can be applied several systems of forest use, which differ basically by the place where the slivering is done. This operation can be done at the foot of track, to loader or in the same plant of power generation or storage centers. Depending on where this slivering takes place the sequence of operations will vary as well as the subsequent transport.

11.2.1 Slivered at the foot of track

Once the wood is stacked at the foot of the track, the slivering is carried out with a mobile chipper coupled to a tractor or automotive machine, with a tipping container and own crane. With the crane the chipper is fed and the produced sliver is deposited in the container. A tractor with trailer can also be used to deposit the slivered.

The requirement of a high mobility chipper makes the productivity lower than in the case of using a fixed or semi-mobile chipper.

When the trailer or container is full they move to the final destination.

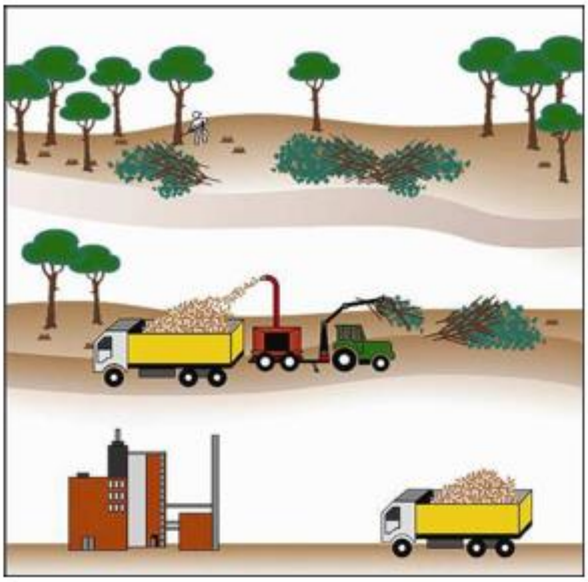

Figure 14: Chipping scheme at the foot of the track (Source: Biomass Observatory).

Apart from the high cost of chipping, due to the low productivity of the machine, this system requires good ground conditions (little slope) and can present problems in times of very humid times or areas. It can be useful in harnessing small areas and when the space of the loader is small.

11.2.2 Slivered in loader

The chipping to loader is realized using a chipper of less mobility than the one of the first system, but heavier, robust and of greater power, reason why the productivity is also greater. That is why in the first place it has to be obtained the wood and transport it to the location of the chipper.

From this point, the chipping is carried out and the sliver is loaded in the corresponding transport means, usually a tractor with trailer or truck with container.

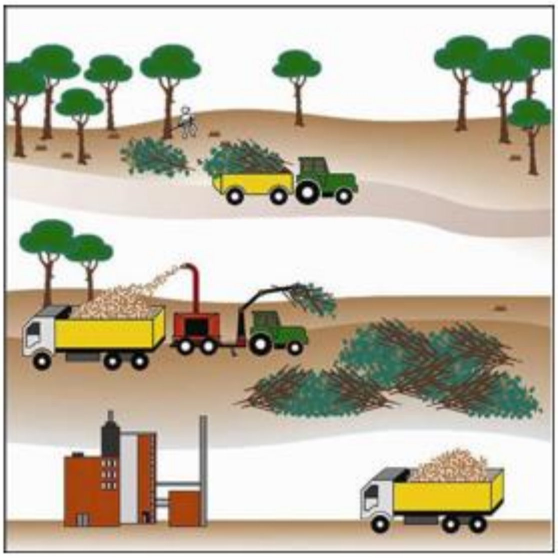

Figure 15: Scheme from slivered in loader (Source: Biomass Observatory).

This systems (slivered at the foot of track and in loader) can be interesting in cases where the plant or warehouse are within a short distance, since in this way the vehicle that performs the unpack (tractor with trailer or truck with container) can also make the transport to plant and does not have to transfer the material to another mean of transport.

11.2.3 Slivered in warehouse

After the tree has been cut, the tree is exposed and stripped and, if necessary to optimize transport, the trunk is cut. The drag to track does not change with respect to the previous cases: it can be done with skidder, tractor with winch or, if the terrain conditions permit, with autoloader.

If the conditions of the terrain and the tracks allow, once the wood is dragged and stacked at the edge of the road, a truck with 3 or 4 axles is usually used, which already carries out the transport directly to the plant.

Once the transport of the wood to the plant or warehouse has been carried out, it can be directly chipped or stored. The chipping is done with fixed or semi-mobile chippers of great power, that have less hourly cost than the movable ones and allow better conditions of control of the quality of chip.

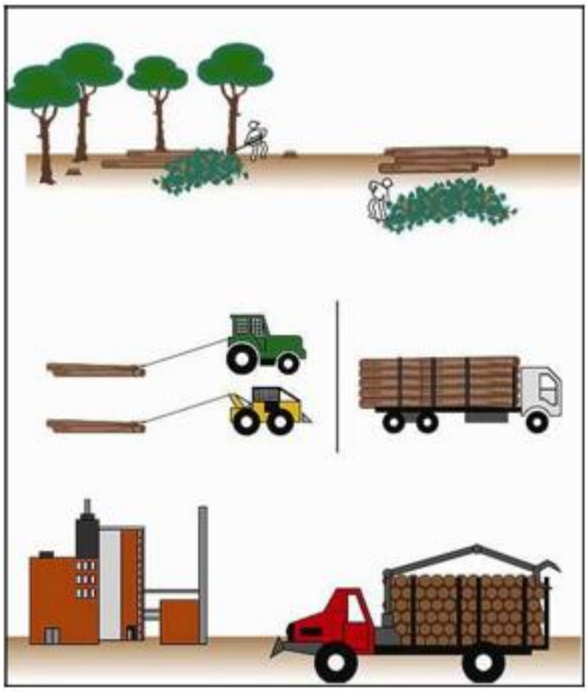

Figure 16: Schematic of chipping of logs in plant (Source: Biomass Observatory).

The splinter in warehouse is the most advisable case for plants with large consumption of sliver, where one of the fundamental pillars for the provisioning is the existence of warehouses or patios to compensate for all type of fluctuations in the supply chain, both anticipated and unforeseen, and also some drying of the material.

11.3 Storage

The drying of the sliver can be done outdoors, with protective textile or under cover.

11.3.1 Outdoor storage

It is the simplest and most economical option. It is usually done under certain circumstances:

- Temporarily in production time
- In the place of chipping for later transport

- In storage areas, well exposed to favour drying (mainly in summer)

Figure 17: Outdoor storage. Source: Afib-CTFC.

11.3.2 Storage with protection

The splinter can be covered with a textile. In the market there are several types of textiles (for example, Toptex or Lester) that have the property of allowing humidity to evaporate but prevent rain or snow from wetting the sliver directly, thereby favouring drying.

In this case, it is advisable that the floor is paved, as this will not increase humidity or chip losses for impurities.

The main advantages of the textile is that it does not require much initial investment and it allows flexibility to choose the storage place (since it is mobile). In addition, its useful life is approximately 5 years.

A disadvantage is that if folds are formed, water accumulates and ceases to be effective.

Figure 18: Storage with protection. Source: Afib-CTFC.

11.3.3 Storage under cover

If it is well designed, drying is safer. It is important to control some design aspects such as ventilation, insulation and access.

Its main advantages are:

- Greater capacity for occupied m2 (if the covered is with walls)
- Effective protection against water (rehydration)
- According to the construction, the contribution of stones and sand by the wind is reduced

The main disadvantages is that it requires a greater initial investment than textiles and that it is fixed. However, an existing warehouse (for example, straw) can also be used for this purpose.

Figure 19: Storage under cover. Source: Rural Energy.

11.4 Supply

The last stage of the process is the distribution and sale of the chip, that is, the transport of the chip from the stores to the points of consumption of the clients.

The cost of this stage depends directly on the transport distance and the capacity of the medium being used, the type of vehicle to be used for the transport of sliver is chosen from the necessary distance to travel, the volume of sliver and the state and quality of roads and access.

To minimize the cost of this transport, another important condition to establish is that customers have to have sufficient capacity to:

- Be able to supply during the period of maximum needs (minimum about 15 days)

- Store the entire capacity of the means of transport used plus 25% to always maintain a minimum sliver stock.

Also it is important to make sure that during the delivery phase the sliver does not get wet or impurities come in, covering it or leaving it safe in case of rain.

To have general idea of the sliver supply, in the next point it is going to be determined the principal clients and their consumption in order to know the energetic demand that our region of study is going to have.

12. Evaluation of potential energy demand and main costumers

The assessment of current and potential energy demand for forest bioenergy is a fundamental pillar in the development of a strategy for the use of biomass for energy, quantities and conditioning factors. In this section an estimation of the energy consumption in thermal applications is made.

Forest biomass heat production facilities require a higher initial investment in comparison to conventional systems with the same level of automation. That is why they are used for constant and elevated thermal needs, where the economy of the biomass price with respect to the fossil fuel price allows to pay off the investment more quickly.

The use of primary forest biomass for heating is especially recommended in homes that meet some of the following requirements:

- Boiler installed with more than 15 years (natural gas or diesel)
- Next renovation
- Future construction (collective buildings)
- With high and constant demand for air conditioning

Thus, depending on the needs of each potential consumer group, it is possible to differentiate between private individuals (house, individual house or block of flats ...), public buildings (town hall, educational centres, penitentiary centres, hospitals ...) and industrial uses (hotels, rural houses, greenhouses, companies, bakeries, dairies, power plants ...).

In the following sections, an estimate is presented for each of the sectors, based on the following considerations:

- Disseminated population and in nuclei: based on average values of population statistics, number of people per household and average area of dwellings.
- Public buildings: based on data obtained from real consumption of equipment of the field of study that are susceptible to install biomass boilers.
- Industries: based on INE (National Institute of Statistics), EUROSTAT and the European Commission.

12.1. Households

12.1.1 Scattered dwellings

Scattered houses are considered as dispersed buildings that do not form specific population nuclei. Therefore, these scattered or rural houses are the best that can be adapted to the implementation of a heating system with domestic biomass boiler because they generally have space to install the boiler, since the sliver is of lower energetic density and takes up more space than an equivalent amount of, for example, diesel.

Municipality	Number scattered houses	Households needs (kWh/hab/year)	Municipality needs (kWh/year)	Biomass by housing (t_{30}/hab/year)	Biomass by municipality (t_{30}/year)
Bellmunt del Priorat	1	14203	14203	4,2	5
Benissanet	27	12731	343737	3,8	103
Capçanes	1	11925	11925	3,6	4
Colldejou	2	14709	29418	4,4	9
Falset	29	14681	425749	4,4	128
Garcia	4	12954	51816	3,9	16
Ginestar	3	12529	37587	3,7	12
Marçà	16	13710	219360	4,1	66
Masroig, el	2	13983	27966	4,2	9
Miravet	21	12294	258174	3,7	78
Mórad'Ebre	48	12879	618192	3,8	185
Móra la Nova	36	12996	467856	3,9	140
Pradell de la	2	15004	30008	4,5	9

Teixeta					
Rasquera	4	13049	52196	3,9	16
Tivissa	20	11381	227620	3,4	68
Total	**216**	**199028**	**2815807**	**59,5**	**848**

Table 31: Potential biomass consumption (t_{30}/year) of scattered houses throughout the study area. Source: AFIB-CTFC from CTE and INE.

In total, if biomass is used to heat all scattered houses from the study area, 848 tonnes of sliver would be needed (at 30% humidity on a wet basis).

12.1.2 Agglomerated dwellings

The agglomerated or grouped dwellings are those that form nuclei of population, with streets, squares and other urban ways.

In these nuclei, one option to take into account is the installation of networks consisting of a central heat generating plant (with a medium or large biomass power boiler) connected to different houses through a distribution network, allowing that the homes can access to this type of energy, competing with the conventional energies, with all the economic and environmental benefits that this entails.

Its application is suitable in buildings or neighbourhoods of new construction or in densified urban environments, since it optimizes the transport of fuel and the distribution of heat. In existing homes, heat networks have small possibilities of immediate implantation, since it would mean a great economic effort in civil works and isolated pipes to connect the heat production plant to the homes, in addition to the large initial investment (which Is already much higher compared to other types of heating with traditional fuels).

This option presents a greater interest in case of work and new urbanization, with a previous preparation of the system of connections, reducing costs and presenting itself as a solution with important ecological and economic benefits. Although the consumption data is presented below in areas of agglomerated population, the difficulties discussed make it impracticable to propose the conversion of these current systems to forest bioenergy.

Municipality	Number agglomerated houses	Households needs (kWh/hab/year)	Municipality needs (kWh/year)	Biomass by housing (t_{30}/hab/year)	Biomass by municipality (t_{30}/year)

Bellmunt del Priorat	133	9590	1275470	2,9	381
Benissanet	352	9246	3254592	2,8	972
Capçanes	153	9315	1425195	2,8	426
Falset	866	10380	8989080	3,1	2676
Garcia	197	9228	1817916	2,8	542
Ginestar	289	9403	2717467	2,8	810
Guiamets	107	9333	998631	2,8	298
Marçà	240	9496	2279040	2,8	680
Masroig	206	10446	2151876	3,1	641
Miravet	261	8549	2231289	2,6	666
Molar	112	11128	1246336	3,3	372
Mórad'Ebre	1531	9398	14388338	2,8	4287
Móra la Nova	970	9168	8892960	2,7	2649
Pradell de la Teixeta	73	10822	790006	3,2	236
Rasquera	269	9160	2464040	2,7	735
Tivissa	616	8408	5179328	2,5	1547
Torre de Fontaubella	56	12281	687736	3,7	205
Total	**6431**	**165351**	**60789300**	**49,4**	**18123**

Table 32: Potential biomass consumption (t_{30}/year) of agglomerated houses throughout the study area. Source: AFIB-CTFC from CTE and INE.

In total, if biomass is used to heat all the agglomerated dwellings in the study area, it would take 18,123 tonnes of sliver (at 30% humidity on a wet basis).

12.2 Public buildings

In general, each type of public equipment has different thermal needs, being the schools and indoor heated swimming pools the ones that consume the most. The application of heating with biomass in these facilities is especially interesting because of the high and constant consumption they usually have and for their exemplary potential.

In order to determine the thermal needs of the municipal facilities in the field of study, the data of real consumption of a total of 7 public buildings have been compiled. It should be kept in mind that not all public buildings are contemplated since some were not susceptible of heating with biomass.

The following table shows the annual heat demand for each equipment studied and its estimated chip consumption.

Municipality	Kind of public building	Number of buildings	Area (m^2)	Energetic demand (kWh/year)	Sliver consumption (t_{30}/year)
Capçanes	School	1	250	37500	10,7
Capçanes	Multipurpose room	1	125	18750	5,4
Capçanes	Old people's couple	1	370	55500	15,9
Capçanes	Young couple	1	40	6000	1,7
Marçà	School	1	400	60000	17,1
Marçà	Place of entities	1	450	75000	21,4
Marçà	Multipurpose room	1	800	120000	34,3
Total		**7**	**2435**	**372750**	**106,5**

Table 33: Estimation of the thermal needs of public facilities in the study area. Source: AFIB-CTFC.

Thus, in the field of study there are about 7 equipment that could be suitable for the installation of boilers of biomass, due to their high thermal needs and the possibility of using biomass.

If all thesepublic buildingsanalysed put boilers of biomass, they would need little more than 100 T30 / year of sliver.

12.3 Industry

In order to estimate the thermal consumption value of biomass of the different industries of the region, it has been selected the companies where the biomass can be presented as a viable option.

Activity sector	Number of companies	Company needs (MWh/com/year)	Sector needs (MWh/year)	Biomass by company (t_{30}/com/year)	Biomass by sector (t_{30}/year)

Manufacture of other non-metallic mineral products	1	7712	7712	2299	2299
Manufacture of beverages	1	1540	1540	459	459
Manufacture of rubber and plàstic products	1	3022	3022	901	901
Manufacture of metal products	1	483	483	144	144
Wood industry	3	603	1810	180	539
Food industry	6	1124	6743	335	2007
Other manufacturing industries	2	252	505	75	150
Total	**15**	**14736**	**21815**	**4393**	**6499**

Table 34: Estimation of the thermal consumption of manufacturing industries in the study area (t30/year) by sector of activity. Source: AFIB-CTFC, EUROSTAT and INE.

In the field of study there are about 15 companies that could be suitable for the installation of boilers of biomass, due to their high thermal needs.

The sector of activity that has greater energy needs is the manufacturing of other non-metallic mineral products, such as the company's manufacturing elements of concrete, gypsum and cement.

If all the manufacturing industries in the region put biomass boilers, they would need about 6,500 t_{30}/year of sliver.

12.4 Balance and conclusions

In case of maximum development of the use of biomass as a source of thermal energy in the sectors considered most interesting, the potential demand for forest chips would be almost 7,453.5 t_{30}/year.

Sector	Biomass (t_{30}/year)
Scattered dwellings	848
Public buildings	106,5
Industry	6499
Total	**7453,5**

Table 35: Annual biomass consumption by sector. Source: self-made.

This value does not include the dwellings of the urban nuclei that, as has been mentioned, technically and economically it is not feasible to incorporate biomass in all these houses. For a space, access and low consumption, it is almost limited to those cases where heat networks can be installed, especially in newly built buildings.

If we compare total biomass consumption per year (7,453.5 t_{30}/year) with the availability of total biomass in the region (573,424 t_{30} of BFP and 267,008 t_{30} of BFP-small) we realize the great opportunity of resources that exist in the region and intensifies the need to adopt measures for the mobilization of the population and of public and private entities. That is why in the following point is developed an action plan in order to have an idea of the tasks to be performed and the time horizon of these to meet our goal: to develop the logistics supply chain.

13. Action plan

1. Assign responsibilities for project implementation: define roles and responsibilities for the decision and implementation of the Action Plan.
2. Dashboard of the Action Plan for the follow-up of the project and its effects in the region: define the system of control indicators that allow to follow the project and make decisions on the orientation of the project. This system must allow obtaining the necessary information for the diffusion of the progress achieved with the project.
3. Diffusion and sensitization to the citizens: it is necessary to approach the project to the citizens, explaining the advantages that are generated in the territory with its implantation. The success of the project is due to the need to create critical mass to create the internal market in the region.
4. Diffusion to the forest sector: it is necessary to transmit the opportunities and potential that are generated. The aim of this diffusion is to seek the maximum participation and involvement of all forest entities present in the region.
5. Diffusion to the local administration (politicians, technicians ...): we must seek the complicity and commitment of the local administration, making the project as an opportunity to break the fear barriers of getting ahead local initiatives. It is vital to seek the maximum participation of local entities to initiate and maintain the project.
6. Grants and funding systems: financing or access to economic resources is one of the most important keys to the development and success of the project.

7. Guidelines for Town Halls: It is necessary to give criteria to the technicians of municipalities to introduce biomass facilities in municipal projects.
8. Public commitment for the implementation of the project: In order to seek the maximum involvement and commitment of the municipalities of the region, a public commitment should be requested to the municipalities to work in the direction of the project, with an act of public signature of the commitment.
9. Biomass-related employment plan: study biomass labor prospects and establish training systems for people in the region to ensure that the occupation is carried out with local personnel.
10. Training in biomass professionals: support the training of the groups involved in the installation and construction so that they can advise and recommend the use of biomass boilers in order to open their business expectations and make a more rational use of the energies.
11. Elaboration of technical plans for forest management and improvement: define how the biomass extraction would be carried out.

TASK	START DATE	END DATE
Assign responsibilities	01/09/2017	01/11/2017
Dashboard of the Action Plan	01/10/2017	01/12/2017
Citizens diffusion	01/11/2017	01/05/2019
Forest sector diffusion	01/11/2017	01/05/2019
Local administration diffusion	01/01/2018	01/05/2019
Grants and funding systems	01/01/2018	01/05/2019
Guidelines for Town Halls	01/03/2018	01/07/2018
Public commitment	01/04/2018	01/07/2019
Employment plan	01/01/2019	01/09/2019
Biomass professional trainings	01/06/2019	01/06/2020
Elaboration of technical plans	01/08/2019	01/09/2020

Table 36: Time horizon of each task. Source: self-made.

13.1 Gantt diagram

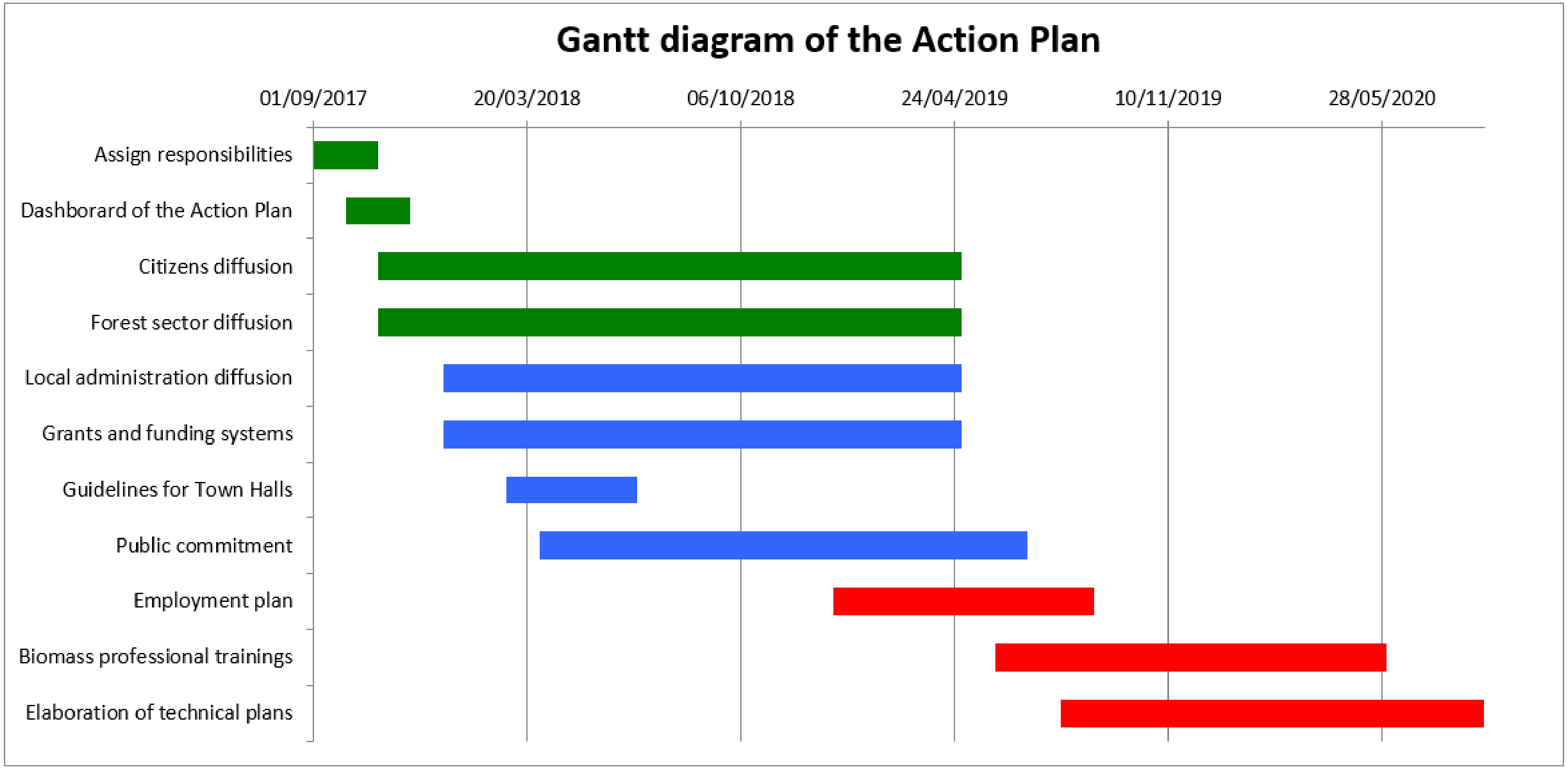

Chart 7: Gantt diagram of the Action Plan. Source: self-made.

14. Conclusions and open lines of the project

Throughout the project, we have seen how investing in renewable energies, in our case in biomass energy, not only is a bet for the future, but also a clear bet on the present. Believing in these energies is no longer just a solution to the current environmental problems of the planet, but also a clear business opportunity for all those investors who risk to bet in this type of energy.

The collaboration, coordination and trust of the three future beneficiaries of this type of energy is also essential for the viability of this type of project. First, it is essential the support of governments and the administration, with a clear plan to disseminate the benefits of the use of this energy on the population and the importance of the aid they offer in financing it. Second, the support of the population to be able to make possible the expansion and settlement of these new systems for the generation of thermal or electric energy from biomass. And finally, future investors that have to make this market a reality.

It has been seen in Catalonia a great availability of resources and facilities for the use of biomass as an energy source. It has been possible to demonstrate that in case of wanting to invest, Priorat and Ribera d'Ebre are the most optimal territories given that they have a quantity of forest resources, facility for their extraction and a clear high energy demand in the region. This is why, for the next step (implementation of the logistics chain), it is only necessary that the three future beneficiaries discussed above solve the cause-effect flowchart (Figure 8) presented in this study.

Although it has been taken a big step in the approach of biomass to Catalonia, there are still many lines to cover and much work to be done.

The first is undoubtedly to carry out this same study from the point of view of economic profitability, in order to present to the investors as financial information the great opportunities that are presented in this new emerging world.

Then, for the implementation of the logistics chain, it is necessary to have plants that work with biomass. So its location is also a point that has remained pending.

And without any doubt, in a near future quantify the amount of forest biomass and analyze the demand of the consumers of this type of energy for the regions discarded in the comparative analysis (Noguera, Gironès, Anoia and Solsonès), since once the first logistic chain will be implemented, all the others will follow it.

The use of biomass as an energy resource will be a chain that when it will start will not stop given the great possibilities it offers.

But perhaps, the most difficult thing is to start, to take the first step.

15. Bibliography

www.plantasdebiomasa.net/que-es-la-biomasa.html
www.sostenibilidad.com/que-es-y-como-funciona-la-biomasa
www.appa.es/04biomasa/04que_es.php
www.idae.es/index.php/relcategoria.1037/id.681/relmenu.322/mod.pags/mem.detalle
www.boe.es/buscar/doc.php?id=DOUE-L-2009-81013
www.europarl.europa.eu/atyourservice/es/displayFtu.html?ftuId=FTU_5.7.4.html
www.plantasdebiomasa.net/tipos-de-biomasa.html
www.idae.es/index.php/idpag.895/relmenu.321/mod.pags/mem.detalle
www.iea.org/
www.theearthproject.com/biomass/
www.avebiom.org/
www.appa.es
www.energynews.es/el-plan-de-la-generalitat-para-impulsar-la-biomasa-movilizara-600-000-toneladas-por-ano-a-partir-de-2020/
www.web.gencat.cat/es/actualitat/detall/Pla-de-Foment-de-la-biomassa-a-Catalunya-00002
www.worldbioenergy.org/
www.boe.es/buscar/doc.php?id=DOUE-L-2009-81013
www.theearthproject.com/
www.idae.es/
www.energias-renovables.com/biomasa/el-objetivo-del-per-20112020-en-biomasa
www.minetad.gob.es/energia/desarrollo/EnergiaRenovable/Paginas/Paner.aspx
www.iea.org/
www.en.wikipedia.org/wiki/Biomass
www.icgc.cat/
www.iefc.cat/
www.icaen.gencat.cat/ca/plans_programes/pecac/
www.agricultura.gencat.cat/ca/departament/dar_estadistiques_observatoris/dar_alimentacio_qualitat/dar_dades_consum_a_catalunya/
www.maps.google.es/
www.idescat.cat/?lang=es
www.icc.cat/
www.creaf.uab.es/mcsc/
www.afib.ctfc.cat/
www.ine.es/

www.codigotecnico.org/

www.mapama.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/ifn3.aspx

www.biomasud.eu/en/biomass-observatory

www.ruralenergy.co.uk/

www.ec.europa.eu/eurostat